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A COMPARATIVE STUDY OF THE UTILITY OF VARIOUS COMMERCIALLY AVAILABLE ORGANIC SOLVENTS FOR THE DETERMINATION OF WHEAT AND FLOUR PIGMENTS[1]

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Since the introduction of the "gasoline color value" test for flour pigmentation by Winton (1911), some form of petroleum hydrocarbon has comprised the solvent employed by the majority of investigators for the extraction of flour pigments. Winton (1911) and Coleman and Christie (1926) used "clear colorless gasoline" and Kent-Jones (1927) in a method employing two extractions specified "petrol" for the first, or carotenoid pigment fraction. Ferrari and Bailey (1929) in developing a spectrophotometric procedure, first employed petroleum ether but later (1929a) changed to high test gasoline. This solvent was again modified by Ferrari (1933) through the addition of 7% of absolute ethyl alcohol and the use of "light cleaners' naphtha" (boiling range 93.3° C. to 160° C.). Whiteside (1931) in an extensive study of the pigments of wheat and flour employed gasoline for the flour studies and a procedure involving pre-treatment with ammoniacal alcohol for the ground wheats. Geddes *et al.* (1934), in developing a simplified colorimetric method, used the naphtha-alcohol (93 to 7) solvent as suggested by Ferrari but employed a higher boiling naphtha (158° C. to 203° C.) known commercially as "varnish makers' naphtha" or "Stoddard's Solvent." Practically the only deviation from the use of petroleum hydrocarbons is that suggested by Simpson (1935), who in a double extraction procedure for determining the "yellowness" and "grade" of flours, employed 100% acetone as a solvent for the carotenoid fraction.

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The requirements of an ideal solvent for the extraction of wheat and flour pigments may be summarized as follows:

High solvent power for the carotenoid pigments of wheat and flour.
Low solvent power for the chlorophyll and flavone pigments.
Ease of clarification, *i.e.*, capability of yielding brilliant extracts free from turbidity.
Uniform composition.
Moderate boiling point, low fire risk, non-toxic, and unobjectionable odor.
Insensitivity to atmospheric or sample moisture.
Low cost and ease of recovery.

On the basis of these criteria, petroleum distillates are far from ideal. They are not uniform in composition; the lower boiling members introduce errors by evaporation, tend to produce turbid extracts and increase the fire risk, while the higher boiling members have a wider distillation range and therefore a more variable composition which may be expected to affect the solvent properties. Turbidity of the extracts may be minimized and the solvent power increased by the addition of 7 to 10% absolute ethyl alcohol but this increases the cost and renders the reagent sensitive to atmospheric or sample moisture, tending to cause separation into two phases. The criticism regarding lack of uniformity in composition does not apply to a specific product or distillate produced according to rigid specifications by any one manufacturer. Workers in this field, however, can not conveniently secure their solvent from one producer and this would appear to be a source of variation in the results obtained by different laboratories.

In view of these considerations, the study reported here was undertaken with the object of securing a chemically homogeneous solvent which would in a large measure fulfil the requirements of an ideal solvent for the quantitative determination of wheat and flour pigments.

Experimental

An extensive range of organic chemicals of high purity is now available in commercial quantities and, accordingly, sixty of the most suitable were secured for a preliminary study. A large composite sample of experimentally milled, unbleached, hard red spring wheat flour was employed, the extracts being prepared and transmittancies determined by the spectrophotometric method outlined in the A. A. C. C. Book of Methods (1935). A Bausch and Lomb spectrophotometer equipped with a scale reading directly in transmittancy was employed. The results are presented in Table I, together with the carotene equivalents in parts per million of flour, boiling ranges, and

operating notes. It must be pointed out that the carotene values can only be considered as an approximate basis of comparison, due to the fact that they are computed from a transmittancy p.p.m. table based on the specific transmissive index (K = 1.9145) for pure carrot carotene in naphtha-alcohol at 4358 Å as reported by Johannson (1935). As the specific transmissive index varies with the solvent employed, it would be necessary to determine this value for each individual solvent in order to secure a precise relation between transmittancy and carotene. The preliminary nature of this phase of the study, however, did not justify the very considerable expenditure of time involved, particularly as a comparison of the transmittancies obtained is quite adequate.

A very wide variation in the apparent amount of pigment extracted will be noted, ranging from 0.17 p.p.m. for *n*-butyraldehyde to 2.62 p.p.m. in the instance of octyl alcohol. In general, the solvent action appears to be related to chemical constitution; this is shown by the means for each type of solvent illustrated graphically in Figure 1,

TABLE I

SUMMARY OF RESULTS OBTAINED IN INITIAL TESTS WITH VARIOUS SOLVENTS

Solvent	Transmittancy of extract (10 cm. cell)	Apparent carotene equivalent	Boiling point	Remarks
	%	*P.p.m.*	°C.	
Hydrocarbons				
Varnish Makers' Naphtha	21.98	1.72	150–180	
Diamylene	28.20	1.44	150–170	Colour bleached out on standing.
Benzene	23.14	1.66	79.6	
Toluene	21.84	1.72	110.7	
Xylene	12.18	2.38	144	
Halogen Derivatives				
Chloroform	17.00	2.01	60–62	Flour floats—necessary to filter.
Carbon tetrachloride	27.90	1.45	76.8	Flour floats—necessary to filter.
Ethylene dichloride (C.C.)	25.87	1.54	83.5	Flour floats—necessary to filter.
Ethylene dichloride (Dow)	22.61	1.68	83.7–84.0	Flour floats—necessary to filter.
Trichlorethane	19.44	1.86	74.1	Flour floats—necessary to filter.
Tetrachlorethane	22.80	1.68	146.3–147.0	Flour floats—necessary to filter
Trichlorethylene	21.14	1.76	86.5–87.5	Flour floats—necessary to filter.
Tetrachlorethylene	27.72	1.45	121–122	Flour floats—necessary to filter.
Propylene dichloride (C.C.)	14.52	2.19	95.9	
Propylene dichloride (Dow)	19.43	1.86	93–97	
n-Amyl chloride	20.55	1.79	102–110	
Mixed amyl chlorides	18.75	1.89	85–109	
Dichloropentanes	83.90	0.20	130–200	
a-Monochlornaphthalene	32.12	1.29	258	Flour floats—necessary to filter.
a-Monobromnaphthalene	40.70	1.02	281.1	Flour floats—necessary to filter.
Alcohols (Primary)				
Methyl alcohol (absolute)	—	—	64.5	Very opalescent; not read.
Ethyl alcohol (95%)	14.73	1.02	—	
Ethyl alcohol (absolute)	12.85	2.33	78.3	All alcohol extracts including primary, secondary and tertiary exhibit a tendency toward slight opalescence.
n-Butyl alcohol	12.78	2.33	117.9	
n-Butyl carbinol	13.23	2.30	134.5–138.5	
iso-Butyl carbinol	11.32	2.47	128.5–132.5	
sec-Butyl carbinol	11.82	2.42	125–131	
n-Hexyl alcohol	12.13	2.39	157	
2-Ethyl-butyl alcohol	14.37	2.20	148.9	
Octyl alcohol	9.92	2.62	184.6	

TABLE I—(*Continued*)

Solvent	Transmittancy of extract (10 cm. cell)	Apparent carotene equivalent	Boiling point	Remarks
	%	*P.p.m.*	°C.	
Alcohols (Secondary)				
Isopropyl alcohol	15.09	2.15	82.3	
Diethyl carbinol	14.27	2.21	99.8–103.8	
Methyl-n-propyl carbinol	13.04	2.32	117.5	
Secondary amyl alcohols	11.81	2.42	113–125	
Methyl amyl alcohol	13.09	2.32	131.4	
Alcohols (Tertiary)				
Dimethylethyl carbinol	10.56	2.54	99.8–103.8	
Tertiary amyl alcohol	14.33	2.21	98–111	
Aldehydes				
n-Butyraldehyde	86.0	0.17	71–78	
Ethers and Oxides				
Ethyl ether (absolute)	23.09	1.66	34.5	
Isopropyl ether	17.03	2.01	67.5	
Dibutyl ether	17.85	1.96	140.9	
Diamyl ether	20.51	1.79	170–200	
Dichlorethyl ether	35.08	1.19	178.5	
Diethylene oxide (dioxan)	26.02	1.52	101.5	
Esters				
Methylacetate (Tech.)	19.55	1.84	52–58	
Methylacetate (C.P.)	24.12	1.62	55–58	
Ethyl formate	12.93	2.32	54.3	
Ethyl acetate (Tech.)	19.17	1.87	70–80	
Ethyl acetate (C.P.)	74.00	0.34	77.4	
Butyl acetate	23.00	1.66	100–135	
Amyl acetate	17.21	2.00	125–155	
Oetyl acetate	21.01	1.77	199.3	
Methyl amyl acetate	22.06	1.71	145.9	
2-Ethyl butyl acetate	36.63	1.14	162.4	
Ketones				
Acetone (C.P.)	23.12	1.66	56.1	
Methyl acetone (Tech.)	16.90	2.01	50–67	
Diacetone	17.54	1.97	130–180	
Methyl amyl ketone	77.00	0.30	147–154	
Hexone	27.55	1.46	113–119	
Furans				
Furfural			158–162	Too dark to read. Solvent is highly colored.
Furfuryl alcohol			165–168	Solvent darkens on standing.
Tetrahydrofurfuryl alcohol	64.9 in 2 cm. cell	2.45	175–180	

which indicate that maximum extraction is obtained with the tertiary alcohols, decreasing through the secondary and primary alcohols, hydrocarbons, ethers and oxides, esters, halogen derivatives and ketones to a minimum in the aldehydes.

These results were examined in the light of the criteria previously outlined and twelve solvents selected which appeared to fulfil at least certain of these requirements. Further extracts were prepared and spectral distribution curves determined. The results of these tests, together with other information pertinent to selection, are summarized in Table II. On the basis of these data, only *n*-butyl alcohol, methyl-amyl alcohol, dimethylethyl-carbinol, dibutyl ether and ethyl and amyl acetates appeared to warrant consideration. Dimethylethyl carbinol can be ruled out on the score of cost, and dibutyl ether on the

basis of risk of explosion during recovery due to the presence of peroxides. The esters, as commercially available, were found to be variable in composition. This leaves only *n*-butyl and methyl amyl alcohols for final consideration. There appears to be very little to choose between these two solvents; methyl amyl alcohol, however, is slightly more expensive, and the commercial product has a somewhat wider boiling range than *n*-butyl alcohol, indicating a rather lower degree of

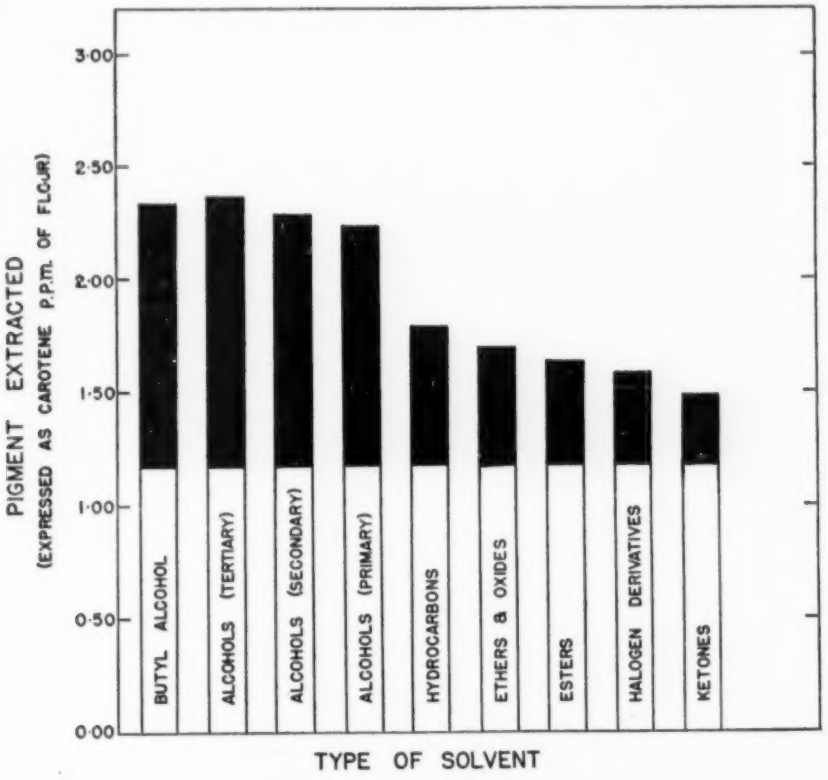

Figure 1. Histogram for means of solvents.

purity. For these reasons, *n*-butyl alcohol was selected and a more extensive series of tests initiated.

Studies with *n*-Butyl Alcohol

Preliminary studies indicated that this solvent showed a tendency to yield slightly turbid extracts which could not be satisfactorily clarified by centrifuging. This difficulty was overcome by saturating the alcohol with water, of which it dissolves about 19.5% of its weight at room temperature. It was ascertained that this treatment does

TABLE II

SUMMARY OF RESULTS OBTAINED WITH TWELVE SELECTED SOLVENTS

Solvent	Transmittancy (10 cm. cell)	Equivalent carotene	Boiling point	Approximate cost	Spectral characteristics of the extract and remarks
	%	*P.p.m.*	°C.	*Cents per pound*	
n-Butyl alcohol	12.78	2.33	117.9	26	Carotenoid
Octyl alcohol	9.92	2.62	184.6	28	Carotenoid and flavone
Methyl-amyl-alcohol	13.09	2.32	131.4	28	Carotenoid
Dimethylethyl carbinol	10.56	2.54	99.8–103.8	52	Carotenoid
Dibutyl ether	17.85	1.96	140.9	36	Carotenoid
Ethyl formate	12.93	2.32	54.3	35	Carotenoid and flavone
Ethyl acetate (Tech.)	19.17	1.87	70–80	20	Carotenoid
Amyl acetate (Pentasol)	17.21	2.00	125–155	32	Carotenoid
Diacetone	17.54	1.97	130–180	25	Solvent and extract turn yellow on standing
Propylene dichloride	14.52	2.19	95.9	9½	Flavone with some carotenoid
Xylene	12.18	2.38	144	—	Flavone with some carotenoid
Tetrahydrofurfuryl alcohol	64.9 (2 cm. cell)	2.45	175–180	—	Flavone; very slightly carotenoid

not affect either the solvent properties or the spectral characteristics of the extracts which are extremely brilliant and free from any trace of turbidity. The water-saturated solvent appears to flocculate the flour to a marked extent. It might be supposed that the addition of such a considerable amount of water to the solvent would result in an increased extraction of the flavone pigments. That this is not the case is illustrated in Figure 2, which shows spectral distribution curves upon extracts obtained with the new and naphtha-alcohol (93 to 7) solvents from flours milled from high and low grade wheats. The general level of the absorption bands for the butyl alcohol extract is practically identical in both cases, whereas the naphtha-alcohol solvent shows a diminished level in the instance of the low grade sample. This "flattening out" of the carotenoid absorption bands is characteristic of the presence of flavone pigments and shows that the naphtha-alcohol solvent extracts a relatively greater amount of these pigments from the low grade material. Advantage was taken of the "indicator" properties of flavone pigments to confirm this point by re-determining the transmittancies of these extracts after the addition of a solution of anhydrous ammonia in absolute alcohol.

In the presence of flavone pigments, this reagent intensifies the colour, thus reducing the transmittancy and increasing the apparent carotene content. Expressed as carotene, this increase was found to

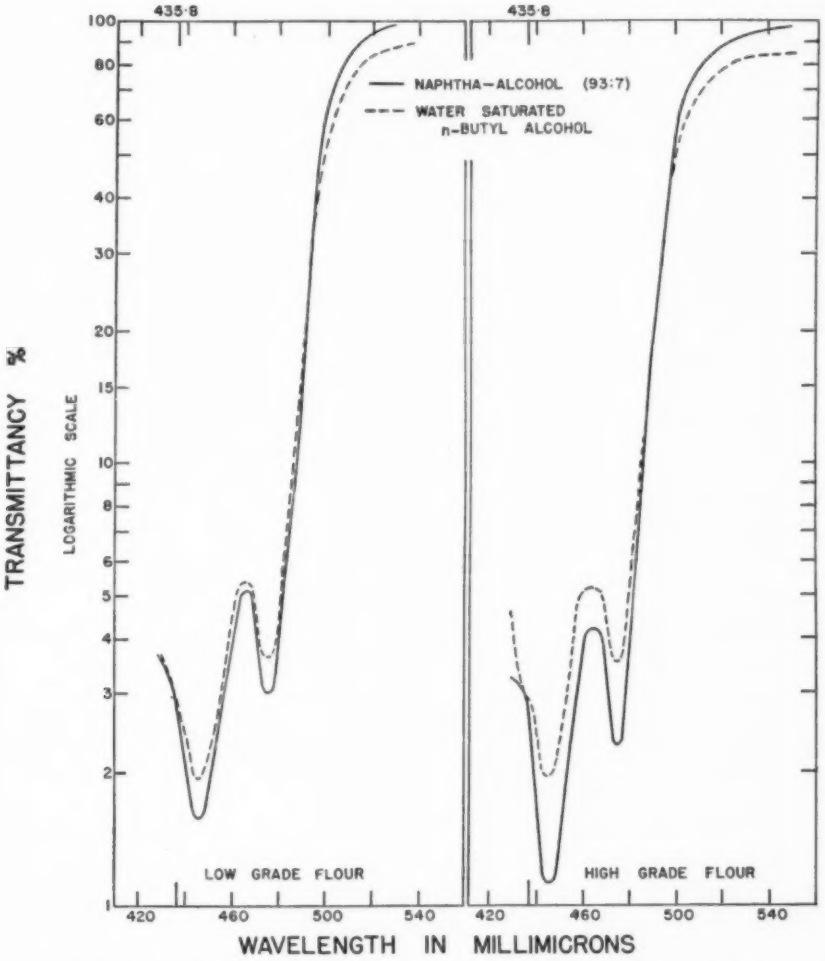

Figure 2. Graph showing spectral distribution curves for N.A. 93 : 7 and *n*-butyl alcohol, using low and high grade flours respectively.

be 0.44 and 0.49 p.p.m. for the high grade sample in the instance of the naphtha-alcohol and water-saturated *n*-butyl alcohol respectively, whereas for the low grade material the corresponding increases were 0.65 and 0.38 p.p.m.

Specific Transmissive Index (K) for Carotene (and Xanthophyll) in Water-Saturated *n*-Butyl Alcohol, Determined in a 10 Cm. Cell as Wavelength 4358 Å

A determination of this value was essential for conversion of the transmittancy values obtained with the new solvent into equivalent carotene content.

The materials employed consisted of highly purified carotene prepared from carrots and finally recrystallized from carbon disulphide and low boiling petroleum ether (30° to 50° C.). It was dried in vacuo (0.001 mm.) at 50° C. over hard paraffin wax. The xanthophyll was recrystallized from a commercial product.

As a criterion of purity, the specific transmissive index of the carotene was determined in petroleum ether and of the xanthophyll in ethyl ether; the respective values obtained were 1.9145 and 2.094, which are in good agreement with data reported in the literature. Schertz (1923) reported the specific transmissive index of carotene in petroleum ether to be 1.9148 while Ferrari and Bailey (1929) gave a value of 1.9165; for xanthophyll in ethyl ether, Schertz (1925) gave 2.089.

The specific transmissive indices in water-saturated *n*-butyl alcohol were determined by preparing stock solutions containing 5 to 10 mg. per litre of the pigments; dilutions were then made and transmittancies determined. From these data (K) is calculated by the following formula:

where $$K = \frac{-\log T}{b_c},$$

T = % transmittancy,

c = concentration of pigment in cg. per litre,

b = cell length in cm.

The results are detailed in Table III and yield mean values of (K) = 1.6632 for carotene and K = 1.7225 for xanthophyll.

Employing the above specific transmissive index for carotene, a conversion curve or table may be readily constructed in which transmittancy is directly expressed as parts per million of carotene in the sample. Using a 20-gram sample, 100 c.c. of water-saturated normal butyl alcohol, and reading the extract in a 10 cm. cell, the concentration of carotene in parts per million of sample equals 3.006 [$-\log_{10} T$] and the results which follow were computed from this relation. Recent work on the pigments of wheat and flour (Markley and Bailey, 1935 and 1935a) indicates that they represent a highly complex mixture containing alpha and beta carotenes, xanthophyll and its esters, tricin and similar flavone pigments, together with other unidentified yellow pigments. Under these circumstances the use of a

TABLE III

SPECIFIC TRANSMISSIVE INDICES (K) FOR CAROTENE AND XANTHOPHYLL IN WATER-SATURATED n-BUTYL ALCOHOL, DETERMINED IN A 10 CM. CELL AT WAVELENGTH 4358Å

Concentration centigrams per litre	Transmittancy %	$-\log T$	K
		Carotene	
.03375	27.50	.56067	1.6612
.04500	17.76	.75056	1.6679
.04950	15.08	.82160	1.6597
.05400	12.63	.89860	1.6640
			Mean 1.6632
		Xanthophyll	
.01778	49.50	.30538	1.7175
.03048	29.71	.52710	1.7293
.03810	22.35	.65072	1.7179
.05334	12.02	.92010	1.7250
			Mean 1.7225

conversion table based upon carrot carotene, which is in itself a variable mixture of the alpha and beta isomers, can only be considered as an approximation. However, the spectral characteristics of the extracts secured with the new solvent are essentially carotenoid in character, and until our knowledge of these pigments is extended the employment of some such arbitrary basis of calculation seems essential.

Comparative Results on Hard Red Spring Wheat Flours Employing the Old and New Solvents

It has been indicated that the water-saturated n-butyl alcohol extracts more carotenoid pigment from cereal products than naphtha-alcohol. As a considerable volume of data has been accumulated with this latter solvent, it became of interest to determine the relation existing between the two. Accordingly, a series of approximately 150 flours was obtained, and carotene determinations conducted with both solvents. These flours were unbleached and experimentally milled from hard red spring wheats grading No. 1 Hard to No. 6 Special and Nos. 1 and 2 C. W. Garnet.

A summary of the results is given in Table IV, while the relation between the corresponding values on each sample is shown by the scatter diagram in Figure 3. From the latter it will be noted that the difference between the carotene results for the two solvents increases with increasing pigment content, which results in a slightly greater differentiation between samples for the n-butyl alcohol solvent. Comparisons between the old and new solvents are being made on ground wheats, durum semolinas and alimentary pastes. The correlation of 0.9325 is quite high and permits of converting carotene

TABLE IV

COMPARISON OF FLOUR CAROTENE VALUES USING NAPHTHA ALCOHOL (93 : 7) AND WATER-SATURATED *n*-BUTYL ALCOHOL AS SOLVENTS

Solvent	Carotene content (13.5% M.B.) Minimum	Maximum	Mean	S.D.	C.V.
	P.p.m.	*P.p.m.*	*P.p.m.*		
Naphtha + alcohol	1.21	2.99	1.77	.354	20.00
n-Butyl alcohol	1.75	3.85	2.33	.470	20.17
	r_{xy} = .9325		5% pt. = .195		
	b_{yx} = 1.2377				

Regression equation	Standard error of prediction
	P.p.m.
Carotene, p.p.m. (butyl-alcohol solvent) = 0.14 + 1.2377 carotene, p.p.m. (naphtha-alcohol solvent)	.170

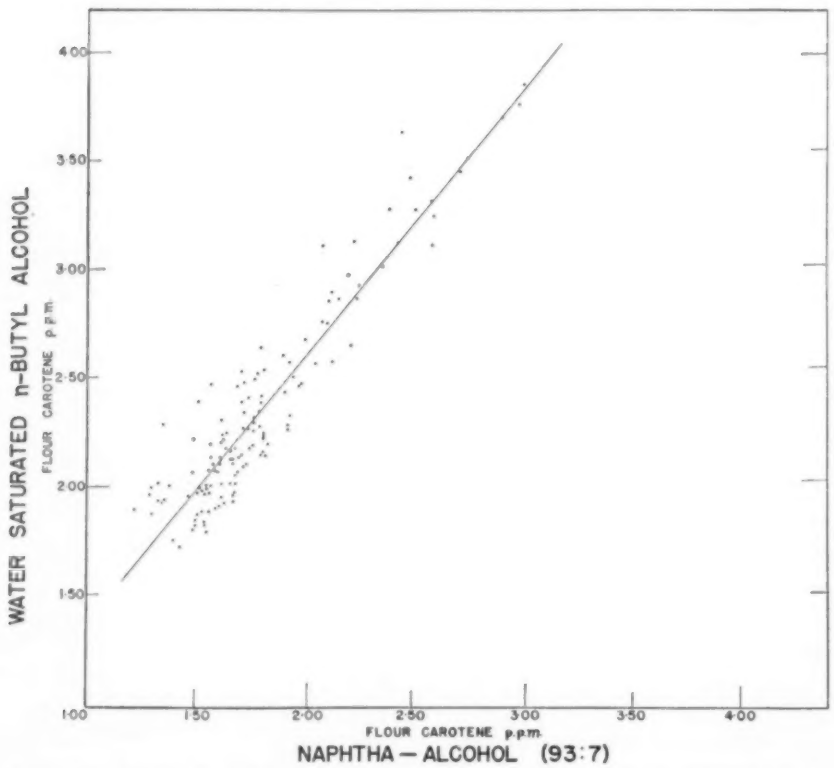

Figure 3. Comparison of results between naphtha-alcohol (93 : 7) and water-saturated *n*-butyl alcohol when applied to 140 hard red spring wheat flours.

results obtained by the naphtha-alcohol to those for the new solvent with a standard error of prediction of 0.170 p.p.m.

Effect of Moisture Content upon the Quantity of Pigment Extracted by Various Solvents

One of the major criticisms of the naphtha-alcohol solvent is its sensitiveness to moisture, either atmospheric or in the sample, and when dealing with flours of rather high moisture content, separation into two phases has frequently been noted. The employment of a water-saturated solvent should tend to minimize such difficulties, and this point was accordingly investigated.

Samples of ground (0.5 mm. Wiley) hard red spring wheat, durum wheat, durum semolina and hard red spring wheat flour were brought to a series of moisture levels by exposure to air of 95% relative humidity for varying lengths of time and pigment determinations conducted using naphtha-alcohol, water-saturated *n*-butyl and methyl-amyl alcohols as solvents. Methyl-amyl alcohol was included because it dissolves considerably less water than *n*-butyl alcohol. The results are summarized in Table V and indicate that variations in moisture have less influence on the carotene values in the instance of the two alcohols, the advantage being slightly in favour of the butyl.

TABLE V

EFFECT OF MOISTURE CONTENT ON QUANTITY OF PIGMENT EXTRACTED BY VARIOUS SOLVENTS

Sample	Range of variation in carotene extracted (13.5% moisture basis)			
	Moisture range	Naphtha-alcohol (93 : 7)	Water-saturated *n*-butyl alcohol	Water-saturated methyl-amyl alcohol
	%	*P.p.m.*	*P.p.m.*	*P.p.m.*
Hard red spring wheat	8.1–12.7	0.41	0.33	0.39
Durum wheat	8.7–11.6	0.61	0.15	0.20
Hard red spring wheat flour	11.8–15.0	0.08	0.05	0.02
Durum semolina	11.4–14.6	0.62	0.11	0.20

Uniformity of Composition and Solvent Properties

In dealing with petroleum hydrocarbon solvents, various investigators have stressed the necessity of invariably using a specific product or distillate in order to ensure uniform results, but no data appear to be available on the relative solvent properties of different fractions. Two and one-half litres each of "varnish makers' naphtha" and commercial *n*-butyl alcohol were fractionated in all-glass apparatus, twelve fractions of 200 c.c. each being collected. The naphtha fractions were

converted to 93 : 7 solvent by the addition to each of 15 c.c. of absolute ethyl alcohol, and the butyl alcohol fractions were each saturated with water. Extracts were then prepared, using a single large sample of flour, and the extracted pigment determined. The results are presented graphically in Figure 4. The naphtha distilled over a range of from 85° C. to 190° C., the corresponding pigment extracted decreasing steadily from 2.01 p.p.m. to 1.64 p.p.m. The butyl alcohol distillation range was 114.8° C. to 118.2° C. and the corresponding carotene contents varied from 2.27 p.p.m. to 2.30 p.p.m., a total variation of only 0.03 p.p.m., which is practically within the error of the determination. This brief study clearly indicates the undesirability of non-homogeneous solvents and confirms the purity and uniform solvent properties of the commercial butyl alcohol employed in these studies.

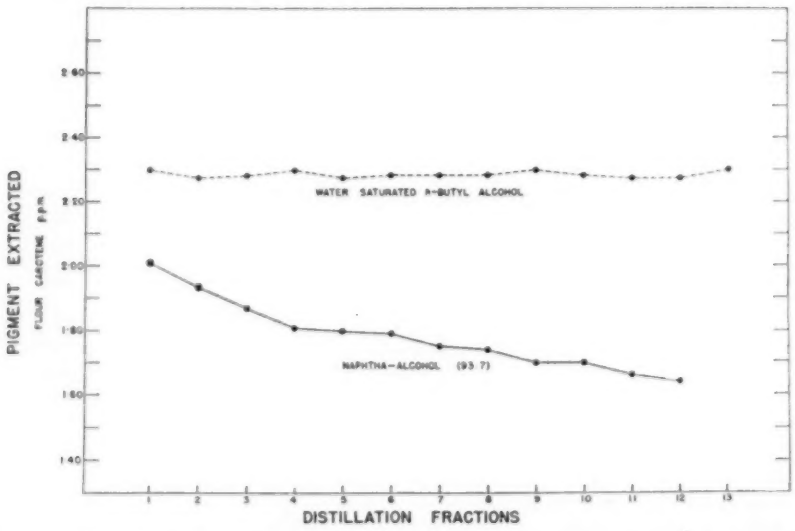

Figure 4. Effect of fractionation of solvent upon the amount of pigment extracted by naphtha-alcohol (93 : 7) and water-saturated *n*-butyl alcohol.

Recovery of Used Solvent

The presence of water in the used butyl alcohol solvent offers no obstacle to recovery by simple distillation. Although the pure alcohol dissolves approximately 19.5% of its weight of water at room temperature, it forms a constant boiling mixture, boiling at 92° C. and containing 37% of water, which mixture on cooling separates into two phases. As the elimination of water from the mixture in the distilling flask proceeds, the temperature rises to the boiling point of the anhydrous alcohol (117.9° C.) and remains at this point until distillation is complete. It is then simply necessary to add a small excess of

water to the distillate, shake thoroughly in order to ensure complete saturation, and allow to stand until clear.

Discussion

Considered in the light of the criteria established for a satisfactory solvent, water-saturated *n*-butyl alcohol possesses high solvent power for the carotenoids and relatively low solvent power for the flavone pigments of flour. The extracts obtained are easily centrifuged or clarified, and are extremely brilliant and free from turbidity; it flocculates the flour to a marked extent. The purity of the commercial product is high, and the various fractions obtained upon distillation possess practically identical solvent properties. The boiling point is moderate (118° C.), the flash point relatively high (43.9° C.), the odor not pronounced, and the toxicity low. As prepared for use by saturation with water, this solvent is unaffected by atmospheric moisture and minimizes the disturbing effect of sample moisture content. It is readily recovered for re-use by simple distillation and in view of this ease of recovery is comparatively inexpensive.

Summary

The requirements of an ideal solvent for wheat and flour pigments are detailed, the deficiencies of petroleum hydrocarbons and admixtures for this purpose are pointed out and the necessity for a more suitable and chemically homogeneous solvent indicated.

Sixty commercially available solvents were submitted to a preliminary survey and a general relation found between efficiency of extraction and chemical constitution. In decreasing order this is: tertiary alcohols, secondary alcohols, primary alcohols, hydrocarbons, ethers and oxides, esters, halogen derivatives, ketones and aldehydes. Twelve of these were subjected to a more detailed study and *n*-butyl alcohol finally selected as the most satisfactory.

This solvent is employed saturated with water and yields brilliant extracts which are essentially carotenoid in character. The specific transmissive indices of carrot carotene and xanthophyll in this solvent are 1.6632 and 1.7225 respectively, determined in a 10 cm. cell at 4358 Å.

Carotene values for 140 hard red spring wheat flours determined with the water-saturated *n*-butyl alcohol and naphtha-alcohol respectively indicate that the former extracts more pigment, particularly in the instance of highly pigmented flours; the correlation found between corresponding values was 0.9325.

The use of water-saturated *n*-butyl alcohol minimizes the disturbing effect of variations in sample moisture which are quite pronounced with naphtha-alcohol.

The purity of commercial *n*-butyl alcohol is high (boiling range 115° to 118° C.) and the various fractions obtained upon distillation possess practically identical solvent properties, thereby permitting recovery for re-use by simple distillation. On the other hand, naphtha has a very wide boiling range and the various fractions differ widely in solvent power.

N-butyl alcohol fulfils the majority of the requirements set forth for an ideal solvent and is regarded as decidedly preferable to petroleum distillates or their admixtures with ethyl alcohol.

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BARLEY AND MALT STUDIES. IV. EXPERIMENTAL MALTING OF BARLEYS GROWN IN 1936 AND SUMMARY DATA FOR THREE YEARS 1934–1936 [1]

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Introduction

The regional investigations on the malting quality of barleys during three crop years have been completed. The investigations on the 1934 and 1935 crops were reported previously in annual summaries (Dickson, Shands, Dickson, and Burkhart, 1935, 1937). Tabular data were not presented in the two earlier reports primarily because it seemed advisable to accumulate three years' results and to test more adequately the methods of malting and of evaluating malts before the data were presented in detailed form.

The present paper, therefore, includes a discussion of the experimental malting of the barleys grown in 1936, and the three years' data for the five varieties grown at the cöoperating agricultural experiment stations. The statistical analysis of the three-year data is presented in abbreviated form to show the relationship of variety, location and season in influencing malting quality. The analysis has been used to determine the response of varieties to locations, seasons, and years.

The three years' data, the writers believe, are not enough to warrant conclusive statements regarding malting quality or methods. Seasonal conditions during the three years have been shown to play such an important rôle in the determination of quality that additional investigations are necessary before final conclusions are drawn. Some of the stations have not submitted samples in all of the three years, thus making the data for those particular stations of less value for the

[1] Based on cooperative investigations between the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, and the Wisconsin Agricultural Experiment Station. The cooperative investigations include the agricultural experiment stations of California, Colorado, Illinois, Iowa, Michigan, Minnesota, Montana, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin, where the uniform barley varietal series are grown each year. The Federal W.P.A. has contributed to the research program during the past year through a grant under the University of Wisconsin W.P.A. Project 425. The United States Maltsters Association has cooperated through an industrial fellowship grant to the University of Wisconsin.

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regional study of malting quality. The writers feel, however, that the results should be presented in some detail to serve as a report of the investigations in progress.

The investigations on the development of methods for the evaluation of malting quality have been continued. The study of the malting procedure on an experimental scale and the comparison of the malts produced with those made by the commercial houses have required considerable time. The investigations on the physiology of malting have been continued to determine the relative importance of moisture, temperature, and time in processing different lots of barley. The results of these physiological investigations have been useful in the interpretation of results obtained in the routine procedure employed in the comparison of barleys in the regional study.

The data presented in this paper were obtained from barleys grown at a number of cooperating experimental stations and a great deal of credit is due the agronomists at these stations. It is by such cooperation that a study of this kind is made possible.

Varieties Used

Five varieties of barley were used in this study. A brief description of each follows:

Oderbrucker (Wisconsin Pedigree 5-1) is a six-rowed, rough-awned variety with white kernels. Oderbrucker was selected at the Wisconsin Agricultural Experiment Station from stock obtained from the Ontario Agricultural College at Guelph. The original importation was from Germany. The Wisconsin Oderbrucker was distributed in 1908.

Wisconsin Barbless (Wisconsin Pedigree 38) is a six-rowed, smooth-awned white-kerneled variety. It is a variety of hybrid origin selected from the cross Oderbrucker × Lion at the Wisconsin Agricultural Experiment Station. This variety was released to the farmers in 1929–1930.

Velvet (Minnesota No. 447) is a six-rowed, smooth-awned, white-kerneled variety. Velvet is a selection from a cross of a smooth-awned segregate of Manchuria × Lion with Luth (a Manchuria selection). It was produced by the coöperative work of the Minnesota Agricultural Experiment Station and the United States Department of Agriculture. It was released in 1926.

Manchuria (North Dakota 2121) is a six-rowed, rough-awned variety having both blue and white kernels. It was selected from an old Manchuria variety at the North Dakota Agricultural Experiment Station in 1901. It was distributed to farmers in 1920.

Trebi (C. I. No. 936) is a six-rowed, rough-awned variety and has large blue kernels. It is a selection from an imported lot of seed obtained by the United States Department of Agriculture from the south side of the Black Sea in 1905. The selection was made in 1909 by H. V. Harlan, of the United States Department of Agriculture, at the Minnesota Agricultural Experiment Station. It was released for commercial production in 1918.

Study of Malting Controls

The checking of methods and procedures of malting in the comparative study of a large number of barleys has been accomplished in part by the use of "malting controls." For this purpose relatively large lots of barley were obtained each year from the bulk grain produced in the increase fields on the University Farms at Madison. These lots were cleaned, thoroughly mixed and stored, and were used as controls in each of the malting series and for special studies on methods. The Wisconsin Barbless was used in 1934 and 1935. Two controls were used in 1936, Wisconsin Barbless and Oderbrucker.

The malting controls were included with each group of barleys malted and analyzed. In addition the controls from the previous years were used in one or two of the first series of barleys malted the following year in order to have a direct comparison between the barleys of the successive seasons and to check methods of malting by comparing with the previous year's results. The data obtained from these malting controls have been used in determining the variability between the five to ten different malting runs made each year in the malting chamber. The summary data on variability of the malting controls for the past three years and standard deviations are presented in Table I.

The data show considerable range in variability for the different determinations. The maximum variation in the moisture content reached in the steep in 1934–1935 was 0.9% above and below the mean. The moisture content reached in the steep in the 1935–1936 Wisconsin Barbless controls varied from 1.3% above to 1.1% below the mean moisture content with the same steep time. The moisture content reached in the steep for Wisconsin Barbless in the 1936–1937 runs was higher (mean moisture content 48.1%) and varied from less than 0.4% below in one malting to 0.8% above. The maximum variation in the moisture content of the steeped barley in the Oderbrucker control was 1.1% above and 0.5% below the mean. The moisture content of the barley at the end of the six-day germination period was more variable than after steeping. The maximum variation in moisture content above and below the mean was as follows: in 1934, 1.6% above, 0.5%

TABLE I

VARIABILITY OF MALTING CONTROLS USED IN EACH MALTING SERIES IN THE LARGE UNIT. SUMMARY OF FIVE SERIES WITH ONE VARIETY IN 1934–1935, EIGHT SERIES WITH ONE VARIETY IN 1935–1936, AND SEVEN SERIES EACH FOR TWO VARIETIES IN 1936–1937[1]

Barley variety and year	Calculations	Moisture content reached in steep	Moisture content at end of germination	Moisture content of dried malt	Recovery of malt from barley dry basis	Kernel weight of malt dry basis	Extract dry basis	Total nitrogen in malt	Soluble nitrogen in wort	Diastatic power
		%	%	%	%	*Mg.*	%	%	%	°*L.*
Wisconsin Barbless Barley sample No. 46, 1934–1935	Mean	45.5	49.3	3.0	84.5	28.5	70.9	2.43	0.681	72.0
	Standard deviation	.663	.870	.870	1.035	.424	.794	.041	.031	13.89
	5% point	1.9	2.5	2.5	2.9	1.2	2.2	0.12	0.09	39.3
5 series	Coefficient of variability	1.458	1.766	28.818	1.225	1.489	1.120	1.706	4.599	19.296
Wisconsin Barbless Barley sample No. 336, 1935–1936	Mean	45.4	46.5	5.2	87.1	26.94	74.9	2.10	0.646	137.1
	Standard deviation	.889	.926	.621	2.009	.672	.441	.037	.017	10.37
	5% point	2.0	2.1	1.4	4.6	1.5	1.0	0.07	0.04	23.9
8 series	Coefficient of variability	1.960	1.990	12.000	2.310	2.490	0.588	1.765	2.576	7.56
Wisconsin Barbless Barley sample No. 466, 1936–1937	Mean	48.1	45.6	4.5	91.0	22.76	67.8	2.19	.593	97.3
	Standard deviation	.441	.689	.619	1.249	.316	.138	.037	.017	10.20
	5% point	1.0	1.6	1.5	2.9	0.7	0.3	0.09	0.04	24.1
7 series	Coefficient of variability	.910	1.510	13.720	1.370	1.390	.200	1.715	2.920	10.480
Oderbrucker Barley sample No. 464, 1936–1937	Mean	46.3	45.4	4.8	89.5	23.67	73.7	1.99	0.674	146.6
	Standard deviation	.297	.573	.570	.772	.706	.368	.120	.012	18.57
	5% point	0.7	1.3	1.3	1.8	1.7	0.9	0.28	0.03	43.9
7 series	Coefficient of variability	.640	1.260	11.850	.860	2.980	.499	6.027	1.720	12.670

[1] Barleys were all grown for six days in malting chamber.

below; in 1935, 1.3% above, 1.2% below; and in 1936, 1.1% above, 0.7% below for Wisconsin Barbless, and 3.8% above and 2.3% below the mean for Oderbrucker. This was due in part to the slight variations in relative humidity within the chamber, especially during the last day of germination, and represents more variability than actually existed during the germination period because water was added to bring the samples to a given weight each day. The moisture content of the dried malt was rather variable in terms of the coefficient of variability. The actual variation, however, was less than 1% above and below the mean except in the malting series of the first year, which ranged from 2.1 to 4.0% moisture content in the dried malt. The mean recovery of malt from barley was significantly lower for Wisconsin Barbless in 1934–1935 than in the other two series. The somewhat higher moisture content used during the germination period and perhaps the use of less accurate methods of determining recovery were partly responsible for this lower recovery. The variability in kernel weight due to the combined influence of malting and determination was greater in three out of the four series than the limits suggested

by Shands (1937) for determinations alone. The variability in kernel weight in the malting controls, however, was not correlated with moisture content at the end of the germination period, which suggests that the range of variation in kernel weight in these series was not greatly influenced by malting conditions. Moisture studies have shown that there is a high correlation at the end of the germination period between moisture content and kernel weight. The total nitrogen was highly variable, especially in the Oderbrucker controls. Experiments to determine the variability in analytical methods, not reported in the present paper, suggest that most of this error has been in sampling the ground material for nitrogen determinations. The accuracy has been improved recently by the use of the Wiley Mill to grind the malts for moisture and nitrogen determinations. Diastatic power has shown a variability higher than any of the other determinations except moisture content of the dried malt. Inasmuch as diastatic power is greatly influenced by drying conditions and the moisture content to which the malts are dried, there is evidently a direct relationship between the variability in moisture content and diastatic power. The variability in extract yield was relatively low in all cases, with an average standard deviation of 0.437% or approximately twice that for the determination of extract alone.

The variability between malting controls, as presented in summary form in Table I, includes all sources of variation between the different runs of a given year. The variation within individual runs has been much less. The methods in general, however, have been sufficiently accurate to evaluate differences between varieties, stations and seasons.

The variation between different malting runs in the malting chamber, while accurate enough to show differences between varieties, stations and years, needs further study especially with relation to moisture control in the chamber and to drying to a more uniform moisture content. Changes of 2 to 3% in moisture content during the germination process are reflected in malt recovery from the barley, in soluble nitrogen in the wort and in diastatic power of the malts. Improvements in moisture control in the malting chamber by means of a humidistatic control of the water spray in the chamber and some means of stopping drying of the different samples at more nearly the same moisture content will do much to reduce the variations now present in the malting procedure.

Comparison of Five Varieties of Barley Grown in Uniform Regional Series in 1936

Four varieties of barley, Oderbrucker, Wisconsin Barbless, Velvet, and Manchuria, were grown at eleven experiment stations in 1936.

Trebi was grown at ten stations. The seasonal conditions at most of the stations in the upper Mississippi Valley were very unfavorable due to the hot, dry weather during the heading and ripening period. The unfavorable weather conditions placed the earlier maturing varieties at a comparative advantage in yield, plumpness of kernel and malting quality. In general, however, the varieties remained in essentially the same relative order for the major malting factors at the different stations and in the average for all stations as in the two previous years. The data for the barleys grown in 1936 are presented in comparison with the results for the two previous years in Tables II to XXII and in summary form for the five varieties in Table XXIII. Location where grown appears to be the greatest factor influencing yield, with variety and year less important.

The influence of the hot, dry season and the period of maturity of the varieties upon quality is well illustrated in the five varieties grown at the widely separated stations. Yields of all varieties were reduced in 1936. The test weight of Wisconsin Barbless barley was below that of the two previous years. The relative differences between 1935 and 1936 in yield, kernel weight and extract of Wisconsin Barbless, in contrast to Manchuria and Velvet, show the different reaction of late and early maturing varieties. (See Tables II, III, V and XV, and

TABLE II

AVERAGE YIELD PER ACRE OF THE FIVE VARIETIES OF BARLEY GROWN IN THE REGIONAL SERIES IN 1934, 1935 AND 1936

Variety	Year	Location where barley was grown													Average[2]
		East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg,[1] Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Nebr.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Oderbrucker	1934	27.5	—	—	10.0	13.8	19.8	—	11.7	21.5	—	46.8	59.7	—	26.3
	1935	25.6	39.5	—	43.0	40.4	35.3	21.1	15.3	25.0	17.7	58.3	32.6	—	32.2
	1936	31.8	42.9	30.8	16.1	36.5	39.5	28.5	11.9	—	—	54.1	56.7	20.0	33.5
Wisconsin Barbless	1934	35.9	—	—	10.7	22.1	30.5	—	25.2	31.1	—	80.5	—	—	33.7
	1935	45.8	45.7	—	57.0	72.3	43.6	38.7	27.8	48.7	28.7	82.8	65.4	—	50.6
	1936	43.0	45.9	35.5	18.9	45.0	43.5	32.9	13.1	—	—	70.4	74.4	21.0	40.3
Velvet	1934	29.6	—	—	15.3	18.5	29.9	—	22.3	30.0	—	73.9	85.2	—	38.1
	1935	37.5	41.6	—	47.0	56.5	30.5	30.4	21.7	42.3	18.4	82.4	45.4	—	41.2
	1936	36.7	45.7	30.2	15.0	39.4	44.4	27.1	16.9	—	—	72.0	68.7	14.0	37.3
Manchuria	1934	21.6	—	—	14.3	15.8	31.4	—	18.7	29.6	—	74.9	59.4	—	33.2
	1935	24.2	40.8	—	41.5	53.5	27.1	17.3	13.6	46.4	13.9	68.1	29.3	—	34.1
	1936	25.7	36.7	29.1	6.8	38.0	41.8	24.6	11.9	—	—	57.2	56.7	23.0	32.0
Trebi	1934	32.7	—	—	18.6	25.3	39.6	—	44.6	38.0	—	126.8	73.6	—	49.9
	1935	29.0	53.0	—	46.8	66.9	39.2	27.4	29.9	61.9	17.7	92.9	32.8	—	45.2
	1936	34.3	65.7	36.5	19.0	55.9	63.5	42.5	24.8	—	—	80.5	78.9	—	50.2

[1] Barley grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.

[2] Averages of all stations reporting for each year, therefore not comparable between years. See Table XXIII for comparable averages for six stations.

TABLE III

Bushel Weight of Barley in Pounds, Dry Basis, of the Five Varieties of Barley Grown in the Regional Series in 1934, 1935, and 1936

Variety	Year	Location where barley was grown														Average[3]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg,[1] Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Oderbrucker	1934	—	39.3	—	—	36.7	42.4	40.4	—	41.6	42.4	—	43.8	41.9	—	41.1
	1935	34.7	40.6	41.9	—	41.6	43.1	—	34.8	26.1	26.9	37.0	45.6	45.1	46.4	38.9
	1936	—	40.3	42.5	44.6	38.5	41.1	41.6	40.5	32.1	—	—	43.8	42.0	44.9	41.1
Wisconsin Barbless	1934	—	40.4	—	—	35.7	—	37.5	—	41.7	39.8	—	43.4	—	—	39.7
	1935	36.0	40.1	40.2	—	42.0	43.1	—	38.6	30.7	34.4	39.9	45.9	46.1	46.5	40.3
	1936	—	35.6	39.2	40.9	35.8	40.9	40.6	39.5	30.5	—	—	43.6	41.0	45.3	39.4
Velvet	1934	—	40.0	—	—	36.1	41.4	39.6	—	43.5	41.4	—	44.5	42.2	—	41.1
	1935	20.6	39.5	41.4	—	41.1	44.2	—	39.2	30.9	33.2	39.6	44.9	46.3	—	38.3
	1936	—	38.1	42.0	45.1	37.5	42.0	42.4	42.8	35.1	—	—	43.4	41.4	45.2	41.4
Manchuria	1934	—	40.2	—	—	36.0	41.4	37.3	—	43.8	39.4	—	44.4	39.8	—	40.3
	1935	35.7	38.4	39.6	—	40.6	43.8	—	35.8	30.0	31.3	36.6	46.3	46.1	46.6	39.2
	1936	—	35.9	42.2	45.0	37.2	41.1[2]	43.4	36.2	33.6	—	—	43.9	39.8	43.7	40.2
Trebi	1934	—	40.8	—	—	34.6	39.9	37.7	—	40.1	39.6	—	43.5	40.0	—	39.5
	1935	31.1	37.4	40.0	—	39.4	42.4	—	35.4	33.3	34.1	37.0	44.5	44.9	—	38.1
	1936	—	34.8	43.1	43.7	37.2	40.3	41.2	40.0	35.2	—	—	41.5	39.9	—	39.7

[1] Barleys grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) was substituted for Manchuria (N. Dak. 2121), which was not furnished from the Waseca station in 1936.
[3] Averages of all stations reporting for each year, therefore not comparable between years. See Table XXIII for comparable averages for six stations.

TABLE IV

Bushel Weight of Malt in Pounds, 4% Moisture Basis, for Malts from the Five Varieties of Barley Grown in the Regional Series in 1934, 1935, and 1936

Variety	Year	Location where barley was grown														Average[3]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg,[1] Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Oberbrucker	1934	—	35.3	—	—	33.9	36.9	—	—	36.5	36.1	—	40.0	36.8	—	36.5
	1935	33.5	37.5	39.1	—	38.9	35.4	—	32.4	24.0	32.2	33.3	40.6	39.8	38.7	34.5
	1936	—	36.3	37.4	38.4	34.4	34.2	34.2	34.7	27.7	—	—	38.3	37.2	38.0	35.5
Wisconsin Barbless	1934	—	35.4	—	—	33.9	36.6	—	—	37.1	37.2	—	39.7	—	—	36.6
	1935	34.9	36.2	37.4	—	38.8	37.7	—	35.4	29.6	—	36.0	42.8	40.8	41.3	37.3
	1936	—	33.5	35.1	36.6	31.8	37.5	34.2	33.8	27.2	—	—	41.2	37.6	39.5	35.3
Velvet	1934	—	34.6	—	—	34.6	35.7	—	—	38.3	36.2	—	40.0	37.6	—	36.7
	1935	42.4	36.1	38.2	—	38.2	37.1	—	35.3	28.8	35.2	34.2	40.9	41.2	—	37.0
	1936	—	34.8	36.0	38.1	33.8	35.2	35.0	34.6	30.7	—	—	39.2	36.6	39.1	35.7
Manchuria	1934	—	35.5	—	—	34.3	35.5	—	—	36.4	40.3	—	39.3	35.4	—	36.7
	1935	32.0	34.2	34.7	—	37.2	35.9	—	32.8	26.3	29.4	33.3	40.2	40.7	40.6	34.8
	1936	—	33.0	35.3	37.4	32.1	34.5[2]	34.3	33.5	28.4	—	—	37.9	36.1	35.4	34.4
Trebi	1934	—	34.9	—	—	33.2	34.1	—	—	35.1	35.7	—	39.4	36.3	—	35.5
	1935	31.8	35.6	36.3	—	36.6	41.2	—	34.4	30.2	—	31.2	36.3	39.8	—	35.3
	1936	—	33.0	37.2	38.3	32.8	34.2	35.3	34.7	27.7	—	—	38.1	35.9	—	34.7

[1] Barleys grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) substituted for Manchuria (N. Dak. 2121) at Waseca in 1936 series.
[3] Averages for all stations reporting for each year, therefore not comparable between years. See Table XXIII for comparable averages from six stations.

summary Table XXIII.) There is likewise a suggestion as in the previous years that the Manchuria and Velvet varieties can withstand dry conditions better than the Oderbrucker and Wisconsin Barbless barleys without impairing malting quality. The contrast between the barleys grown at the upper Mississippi Valley stations and those grown at the stations in the irrigated Intermountain area and California also shows the influence of seasonal conditions upon malting quality (Tables III to XX). The 1936 averages for the varieties

TABLE V

KERNEL WEIGHT OF BARLEY IN MILLIGRAMS, DRY BASIS, EXCEPT 1934 DATA WHICH ARE ON AIR-DRY BASIS. FIVE VARIETIES OF BARLEY GROWN IN REGIONAL SERIES IN 1934, 1935, AND 1936. CALCULATED ON THE BASIS OF WEIGHT OF 400 KERNELS

Variety	Year	Location where barley was grown														Average[4]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg,[2] Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
Oderbrucker	1934[1]	—	33.2	—	—	33.3	30.7	29.9	—	34.0	29.6	—	35.4	28.5	—	31.8[3]
	1935	25.7	30.3	29.1	—	31.1	24.8	—	21.7[2]	12.4	14.8	21.0	32.6	32.8	34.4	25.9
	1936	—	29.6	26.7	29.1	24.8	22.5	22.9	23.0[2]	18.0	—	—	31.1	27.8	30.4	26.0
Wisconsin Barbless	1934[1]	—	34.0	—	—	35.9	29.2	30.3	—	35.9	30.4	—	37.2	—	—	33.3
	1935	26.0	29.5	29.7	—	31.7	28.8	—	24.0	15.8	22.3	24.9	34.4	31.7	38.5	28.1
	1936	—	28.0	26.7	25.2	22.8	25.6	25.7	24.5	18.8	—	—	35.7	27.4	33.7	26.7
Velvet	1934[1]	—	31.5	—	—	32.3	27.3	29.0	—	33.9	29.5	—	36.1	26.9	—	30.8
	1935	21.8	26.1	29.3	—	28.6	25.0	—	21.3	14.7	18.3	21.9	31.0	33.1	—	24.6
	1936	—	27.5	25.8	28.8	24.1	24.0	22.1	24.3	19.7	—	—	31.1	27.8	28.4	25.8
Manchuria	1934[1]	—	31.1	—	—	31.2	26.8	26.1	—	31.3	27.4	—	34.7	23.8	—	29.0
	1935	21.7	25.6	25.8	—	29.1	25.1	—	19.1	13.9	19.1	19.6	31.7	28.3	32.6	24.3
	1936	—	25.3	25.4	26.7	23.8	22.8[3]	23.4	21.7	19.9	—	—	30.1	24.3	28.2	24.7
Trebi	1934[1]	—	42.8	—	—	41.6	37.7	40.2	—	40.9	40.6	—	42.9	36.1	—	40.4
	1935	28.8	34.8	35.4	—	38.1	34.5	—	28.3	23.1	27.1	27.2	40.5	36.5	—	32.2
	1936	—	30.1	37.5	39.1	32.1	30.4	33.0	31.6	27.4	—	—	39.2	32.1	—	33.3

[1] Air-dry basis for 1934, all other weights on dry basis. The averages for kernel weights in 1934 calculated on the dry basis by using 12% moisture for the barley are as follows: Oderbrucker 28.0, Wisconsin Barbless 29.3, Velvet 27.1, Manchuria 25.5, Trebi 35.5 mg., respectively.

[2] Barleys grown at Ames in 1936, and at Emmetsburg, Iowa, in 1935.

[3] Manchuria (Minn. 184) data given instead of Manchuria (N. Dak. 2121), as the latter variety was not grown in 1936.

[4] Averages for all stations; see Table XXIII for comparable averages.

grown at all stations are not greatly different from the general averages in the 1935 season. (See averages given in Tables II to XXII.) A study of the data for the barleys from the stations in the Mississippi Valley area in 1936 and the averages for the six stations supplying samples for each of the three years shows a marked inferiority in the quality of those barleys as compared with the barleys produced in 1935 (Table XXIII). The barleys from these stations more nearly reflect the general low quality of the 1936 crop of barley than do the averages from all of the stations. The survey of the individual factors used in

evaluating the barleys and malts shows in more detail the seasonal and regional effects upon quality.

The yields of the five varieties of barley varied widely at the different stations. The average yield of the varieties at the six comparable stations for the three years was lower than in 1935 (Table XXIII). The average yield of Oderbrucker at the eleven stations reporting was higher in 1936 than the average for all stations in either of the previous seasons. On the same basis of averaging, Velvet and Manchuria produced yields only slightly less than in 1935. The aver-

TABLE VI

KERNEL WEIGHT OF MALT IN MILLIGRAMS, DRY BASIS, FROM BARLEYS GROWN IN REGIONAL SERIES IN 1934, 1935, AND 1936. CALCULATED ON THE BASIS OF 400 KERNELS

Variety	Year	Location where barley was grown														Average[3]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg,[1] Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		Mg.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*
Oderbrucker	1934	—	26.1	—	—	26.9	29.1	24.9	—	27.4	23.2	—	28.9	23.2	—	25.6
	1935	21.8	25.0	25.3	—	28.4	21.5	—	17.2[1]	11.2	19.0	18.6	28.4	26.6	28.5	22.6
	1936	—	26.4	24.6	25.7	20.6	20.8	20.7	20.4[1]	16.1	—	—	26.7	25.0	26.4	23.0
Wisconsin Barbless	1934	—	27.5	—	—	30.4	23.8	25.4	—	20.2	23.5	—	31.5	—	—	26.0
	1935	22.6	25.5	25.0	—	27.9	25.9	—	20.7	14.8	—	22.6	30.0	27.1	32.9	25.0
	1936	—	32.4	23.4	22.9	21.2	20.5	22.2	21.6	16.3	—	—	31.9	24.5	29.5	24.2
Velvet	1934	—	27.0	—	—	25.2	20.4	23.8	—	27.1	22.3	—	29.5	21.8	—	24.6
	1935	18.8	22.1	25.4	—	24.3	22.1	—	16.9	12.8	15.8	18.5	26.8	28.3	—	24.6
	1936	—	23.8	23.5	25.0	20.4	22.1	20.7	22.1	17.4	—	—	29.0	24.3	25.8	23.1
Manchuria	1934	—	25.4	—	—	23.8	20.3	22.2	—	24.1	21.1	—	27.0	19.6	—	22.9
	1935	19.7	22.2	21.5	—	25.5	21.7	—	17.0	12.5	15.9	17.8	27.7	24.3	28.3	21.2
	1936	—	23.2	22.3	23.2	21.3[2]	19.6	21.2	20.2	13.8	—	—	25.7	21.7	25.3	21.6
Trebi	1934	—	34.9	—	—	28.7	28.9	35.2	—	33.4	31.5	—	38.7	29.8	—	32.6
	1935	24.4	30.7	30.4	—	33.0	36.9	—	25.0	19.7	—	23.1	31.7	32.6	—	28.7
	1936	—	28.5	33.4	34.5	29.4	27.3	28.7	29.2	19.6	—	—	36.2	28.8	—	29.6

[1] Barley grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) substituted for Manchuria (N. Dak. 2121), as latter not grown at Waseca with series in 1936.
[3] Averages for all stations; see Table XXIII for comparable averages.

age production of Wisconsin Barbless was 10 bushels below 1935. The average yield for Trebi was higher than in either of the previous years. The contrast between yields at the different stations shows clearly the relative behavior of the varieties as well as seasonal conditions at the different stations. The yield data for the three years are given in Table II. The average yields for the six stations that were used in the analysis of variance are given in Table XXIII.

The bushel weight of the 1936 barleys was in general rather low for all varieties grown at most locations in the upper Mississippi Valley area. The average bushel weight of barley and malt from the six

TABLE VII

Skinned and Broken Kernels for the Five Varieties of Barley Grown in the Regional Series in 1934, 1935, and 1936

Variety	Year	Location where barley was grown														Average[3]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg,[1] Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Oderbrucker	1934	—	7.9	—	—	7.8	14.5	5.1	—	5.9	3.6	—	0.9	6.0	—	6.5
	1935	0.7	0.9	2.3	—	1.8	4.0	—	3.2	1.4	0.5	2.4	5.2	8.3	6.8	3.1
	1936	—	1.7	2.4	7.4	2.1	11.7	1.4	3.3	5.7	—	—	4.8	4.9	15.1	5.5
Wisconsin Barbless	1934	—	9.3	—	—	5.3	3.7	3.9	—	9.0	4.9	—	1.2	—	—	5.3
	1935	2.7	2.2	3.4	—	2.8	7.0	—	5.4	0.9	3.2	5.7	10.4	24.2	11.4	6.6
	1936	—	0.3	1.6	5.8	1.5	2.4	0.7	4.5	4.9	—	—	7.4	5.7	22.7	5.2
Velvet	1934	—	9.2	—	—	5.4	7.3	1.1	—	8.5	5.3	—	1.0	5.1	—	5.4
	1935	2.9	1.4	0.8	—	2.7	10.1	—	4.9	1.6	0.6	4.8	8.6	19.3	—	5.2
	1936	—	1.3	1.9	4.8	2.4	9.0	1.0	2.8	3.5	—	—	3.9	12.9	21.7	5.9
Manchuria	1934	—	15.1	—	—	2.9	6.8	1.7	—	14.5	4.1	—	1.6	4.4	—	6.4
	1935	1.0	2.0	2.1	—	1.7	11.8	—	2.3	2.4	1.0	4.7	6.5	18.1	5.4	4.9
	1936	—	0.6	2.9	6.8	2.2	16.2[2]	3.2	3.2	7.9	—	—	6.4	4.2	15.3	6.3
Trebi	1934	—	6.2	—	—	2.6	11.9	3.4	—	5.2	3.2	—	1.1	3.8	—	4.7
	1935	1.1	1.0	0.7	—	2.2	7.0	—	4.3	2.6	2.5	8.8	16.2	28.9	—	6.8
	1936	—	4.0	2.3	7.5	6.0	30.0	1.7	8.6	4.6	—	—	4.8	7.7	—	7.7
Station average		1.7	4.2	2.0	6.5	3.3	10.2	2.3	4.2	5.2	2.9	5.3	5.3	11.0	14.1	—

[1] Barley grown at Emmetsburg in 1935, and at Ames in 1936.
[2] Manchuria (Minn. 184) substituted for Manchuria (N. Dak. 2121) in Waseca series in 1936.
[3] Averages for all stations; see Table XXIII for comparable averages.

TABLE VIII

Weight of Hull of Barley in Per Cent from the Five Varieties of Barley Grown in the Regional Series in 1934, 1935, and 1936

Variety	Year	Location where barley was grown														Average[3]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg,[1] Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Oderbrucker	1934	—	12.0	—	—	12.7	13.1	10.3	—	12.7	11.6	—	13.9	10.9	—	12.1
	1935	11.7	9.9	8.7	—	9.5	11.2	—	12.3	17.7	17.4	12.4	8.2	9.2	7.8	11.3
	1936	—	12.2	12.5	12.0	13.2	13.2	12.9	12.5	17.8	—	—	10.1	11.6	9.2	12.5
Wisconsin Barbless	1934	—	13.2	—	—	12.8	13.3	11.9	—	12.5	13.1	—	11.4	—	—	12.6
	1935	11.7	10.5	10.8	—	9.7	10.0	11.1	11.5	15.2	12.4	12.6	8.2	8.7	8.5	10.8
	1936	—	15.3	13.4	12.1	16.7	14.1	14.2	14.5	18.3	—	—	9.7	11.6	8.4	13.5
Velvet	1934	—	13.4	—	—	11.4	14.8	12.5	—	11.3	11.8	—	11.8	12.9	—	12.5
	1935	13.0	11.1	10.7	—	11.3	8.8	—	12.5	17.3	17.4	11.0	9.4	8.2	—	11.9
	1936	—	12.6	14.0	12.2	14.2	13.6	12.8	13.2	15.2	—	—	10.8	11.6	11.1	12.8
Manchuria	1934	—	12.9	—	—	10.3	12.9	11.2	—	11.5	11.5	—	11.1	11.3	—	11.6
	1935	12.2	10.7	10.7	—	8.6	9.1	—	13.0	13.8	14.0	11.4	8.7	7.3	7.2	10.5
	1936	—	12.3	10.5	10.5	12.5	12.5[2]	10.9	12.8	13.8	—	—	9.9	10.8	8.8	11.4
Trebi	1934	—	15.7	—	—	11.4	12.9	12.0	—	16.7	13.0	—	11.4	12.1	—	13.1
	1935	11.9	9.6	10.0	—	9.7	9.6	—	10.5	14.8	11.7	11.8	7.8	8.1	—	10.4
	1936	—	13.5	12.7	12.6	13.9	12.5	13.5	13.5	14.8	—	—	10.9	11.8	—	13.0

[1] Barley grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) substituted for Manchuria (N. Dak. 2121) in Waseca series in 1936.
[3] Average for all stations; see Table XXIII for comparable averages.

TABLE IX

ENDOSPERM CHARACTER EXPRESSED AS INDEX OF MELLOWNESS IN (*A*) DRY BARLEY, (*B*) BARLEY STEEPED 24 TO 30 HOURS AT 16° C. (60.8° F.) AND DRIED, AND (*C*) IN THE MALT FOR THE FIVE VARIETIES OF BARLEY GROWN IN THE REGIONAL SERIES IN 1934, 1935, AND 1936

The index of mellowness was calculated as follows: number of steely kernels × 0, number of half-steely kernels × ½, and number of mellow kernels × 1, and sums added together

Variety	*A*. Dry barley *B*. Steeped barley *C*. Malt	Year	Stations where barley was grown															Average[3]
			Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsb'g,[1] Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.		
			%	%	%	%	%	%	%	%	%	%	%	%	%	%		%
Oderbrucker	A	1934	—	34.5	—	—	32.5	15.5	11.5	—	29.0	11.5	—	25.5	25.5	—		23.2
	B	1934	—	55.5	—	—	53.0	50.0	—	—	55.0	82.0	—	53.5	46.5	—		56.5
	C	1934	—	92.0	—	—	70.5	88.0	84.0	—	94.0	85.5	—	85.0	81.5	—		85.1
	A	1935	74.5	72.5	85.5	—	66.5	88.5	—	84.0	58.0	51.5	95.0	35.5	37.5	36.5		65.5
	B	1935	94.0	98.5	98.5	—	93.5	100	—	99.0	98.0	99.5	96.5	87.0	89.5	77.0		94.2
	C	1935	96.0	98.5	96.5	—	98.0	96.0	—	92.0	87.0	89.5	98.0	94.5	97.0	97.0		95.0
	A	1936	—	24.0	44.0	54.0	47.5	34.0	35.5	38.0	40.0	—	—	40.0	54.5	43.0		41.3
	B	1936	—	100	99.0	100	97.5	96.0	73.0	96.0	97.5	—	—	97.0	96.0	95.5		95.2
	C	1936	—	100	93.5	98.0	98.5	96.0	98.0	97.0	98.5	—	—	96.5	95.0	96.5		97.0
Wisconsin Barbless	A	1934	—	18.5	—	—	31.0	23.5	13.5	—	26.0	7.5	—	10.5	—	—		18.6
	B	1934	—	90.0	—	—	53.5	59.5	—	—	56.0	78.0	—	48.0	—	—		64.2
	C	1934	—	96.5	—	—	60.5	63.5	78.0	—	88.0	86.0	—	89.0	—	—		80.2
	A	1935	69.0	53.5	78.0	—	61.5	69.0	—	70.0	57.5	63.0	47.5	30.0	44.5	43.5		57.2
	B	1935	94.5	93.0	91.5	—	92.5	98.5	—	92.5	99.0	97.5	96.0	88.5	85.0	82.0		92.5
	C	1935	92.5	94.5	98.5	—	94.0	98.5	—	93.0	92.0	—	96.5	93.0	87.5	97.5		94.3
	A	1936	—	13.0	45.5	53.0	51.0	54.0	31.0	37.5	42.5	—	—	22.5	62.5	47.5		41.8
	B	1936	—	97.0	98.5	100	97.0	98.0	92.0	95.0	100	—	—	99.0	96.0	92.5		96.8
	C	1936	—	100	100	100	97.5	100	100	100	100	—	—	89.0	100	99.0		98.7
Velvet	A	1934	—	34.5	—	—	26.5	17.5	13.5	—	30.5	7.0	—	12.5	20.0	—		20.2
	B	1934	—	78.0	—	—	46.0	52.0	—	—	66.5	79.0	—	47.0	44.0	—		58.9
	C	1934	—	95.5	—	—	63.0	75.0	81.0	—	77.5	89.5	—	94.5	80.5	—		82.1
	A	1935	61.0	62.0	73.0	—	65.5	70.0	—	71.0	57.5	72.0	62.0	30.5	45.0	—		60.9
	B	1935	95.5	90.0	91.5	—	96.0	98.0	—	93.0	96.5	99.0	98.0	84.5	85.5	—		93.4
	C	1935	88.5	92.5	96.0	—	92.5	97.5	—	95.0	94.0	86.5	96.0	88.0	84.0	—		91.9
	A	1936	—	20.0	50.5	57.0	49.0	49.0	38.5	41.5	43.0	—	—	24.0	58.5	45.5		43.3
	B	1936	—	99.5	97.5	100	95.0	89.0	93.0	93.0	97.5	—	—	91.5	91.0	90.0		94.3
	C	1936	—	100	100	98.0	99.5	90.0	90.0	97.0	98.0	—	—	80.5	94.5	98.0		95.0
Manchuria	A	1934	—	35.5	—	—	47.0	18.5	25.0	—	36.0	15.5	—	8.5	25.5	—		26.4
	B	1934	—	88.0	—	—	54.0	83.5	—	—	70.0	81.5	—	46.5	42.0	—		66.5
	C	1934	—	88.0	—	—	81.5	83.5	88.0	—	92.5	90.5	—	87.5	85.0	—		87.1
	A	1935	58.0	77.0	80.0	—	72.0	78.5	—	87.5	56.0	89.0	64.5	42.5	51.0	32.5		65.7
	B	1935	94.5	96.5	90.5	—	95.5	97.0	—	97.5	99.0	99.5	98.0	97.0	96.0	67.0		94.0
	C	1935	95.5	98.5	97.5	—	94.5	95.5	—	92.5	84.0	91.0	96.5	97.0	95.5	97.5		94.6
	A	1936	—	23.5	49.0	53.0	48.5	29.5[2]	43.0	42.0	47.5	—	—	45.5	70.5	45.0		45.2
	B	1936	—	96.5	97.5	99.5	99.5	78.5[2]	95.5	95.0	96.0	—	—	99.5	98.5	96.5		95.7
	C	1936	—	96.5	99.0	100	98.5	93.5[2]	98.0	99.0	98.5	—	—	98.5	98.0	94.0		97.6
Trebi	A	1934	—	27.5	—	—	8.5	13.5	8.0	—	21.5	5.5	—	9.0	12.5	—		13.2
	B	1934	—	49.0	—	—	41.0	36.0	—	—	57.5	35.0	—	45.5	24.0	—		41.1
	C	1934	—	84.0	—	—	75.8	57.5	74.0	—	82.5	78.0	—	65.0	47.0	—		70.5
	A	1935	56.0	61.0	64.5	—	63.0	46.0	—	50.0	37.0	52.0	42.5	29.5	28.0	—		48.1
	B	1935	73.0	88.5	97.5	—	87.0	93.0	—	87.0	86.0	88.0	88.5	73.0	65.0	—		84.2
	C	1935	86.5	97.0	98.0	—	96.0	79.5	—	91.5	94.0	—	97.0	94.5	77.0	—		91.1
	A	1936	—	5.0	29.0	33.0	32.0	21.0	30.5	28.5	42.0	—	—	27.5	23.0	—		27.1
	B	1936	—	78.5	97.0	100	97.5	77.0	84.5	95.0	97.0	—	—	81.5	83.5	—		89.1
	C	1936	—	90.0	93.0	98.0	98.5	95.0	96.5	100	95.5	—	—	74.0	76.0	—		91.6

[1] Barleys grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) substituted for Manchuria (N. Dak. 2121) at Waseca in 1936 series.
[3] Average for all stations; see Table XXIII for comparable averages.

comparable stations was slightly lower than in either of the previous years (Table XXIII). With the exception of Wisconsin Barbless, the average bushel weight based on all stations was higher in 1936 than in 1935. The detailed figures for bushel weight of barley and malt are given in Tables III and IV. Wisconsin Barbless in 1936 was lowest in bushel weight at most of the stations whereas in 1935 this variety ranked highest. The bushel weight of malts from the 1936 barleys was on the average somewhat lower than in the previous year.

TABLE X

ESTIMATED[1] TIME REQUIRED TO STEEP BARLEY TO 46 PER CENT MOISTURE CONTENT FOR THE FIVE VARIETIES OF BARLEY GROWN IN THE REGIONAL SERIES IN 1934, 1935, AND 1936

Variety	Year	Location where barley was grown														Average[4]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg[2] or Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		Hrs.	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*
Oderbrucker	1934	—	33.0	—	—	43.0	28.5	32.5	—	33.0	36.0	—	32.0	28.0	—	33.2
	1935	23.0	45.0	29.5	—	50.0	39.0	—	22.5	11.0	20.0	18.0	36.0	36.0	36.0	30.5
	1936	—	32.0	34.0	38.8	54.0	20.5	27.5	23.0	9.0	—	—	45.5	35.0	35.0	31.9
Wisconsin Barbless	1934	—	39.0	—	—	39.0	30.0	36.5	—	41.5	45.5	—	47.0	—	—	41.1
	1935	24.0	38.5	26.5	—	62.0	47.0	—	33.0	14.5	—	35.0	43.0	44.0	53.0	38.2
	1936	—	34.0	37.0	37.0	26.0	31.0	32.0	29.0	11.0	—	—	51.0	44.0	41.0	33.9
Velvet	1934	—	32.5	—	—	41.0	30.5	33.5	—	27.0	38.0	—	41.0	47.5	—	36.4
	1935	20.5	40.0	29.5	—	45.0	51.0	—	29.5	11.5	15.5	24.5	37.0	48.0	—	32.0
	1936	—	34.5	37.5	38.0	32.0	30.0	28.0	34.0	15.5	—	—	34.5	36.0	29.0	31.7
Manchuria	1934	—	31.0	—	—	35.0	25.5	33.0	—	39.5	28.0	—	39.0	27.0	—	32.2
	1935	18.5	24.5	23.0	—	55.0	36.0	—	22.5	11.0	13.0	22.5	41.0	38.0	39.5	28.7
	1936	—	28.0	30.5	41.5	20.0	19.0[3]	32.0	23.5	10.0	—	—	45.0	23.5	25.0	27.1
Trebi	1934	—	43.0	—	—	49.0	38.0	39.0	—	50.0	42.0	—	53.0	41.0	—	44.4
	1935	19.0	39.5	34.0	—	47.0	35.0	—	24.5	23.5	—	27.5	47.5	36.0	—	33.3
	1936	—	56.0	55.0	52.0	36.5	27.5	48.5	33.0	19.0	—	—	37.0	35.0	—	39.9

[1] Hours were estimated by using the logarithmic graph for water absorption.
[2] Barleys grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[3] Manchuria (Minn. 184) substituted for Manchuria (N. Dak. 2121) in the Waseca series in 1936.
[4] Average for all stations; see Table XXIII for comparable averages.

The kernel weight of barleys and malts in 1936 was somewhat low but for all stations not appreciably lower than in 1935. (See Table XXIII.) However, the kernel weight of both barley and malt was reduced considerably at some stations, including Urbana, Illinois, Madison, Wisconsin, Waseca, Minnesota, and Kanawha, Iowa. There was also a slight reduction in kernel weight in some of the barleys and malts from Bozeman, Montana, Fort Collins, Colorado, and Davis, California. The data on kernel weight of barleys and malts are given in Tables V and VI. The five varieties have maintained the same relative order for kernel weight in the three years.

The data on skinned and broken kernels show relatively little varietal difference in 1936 or the two previous years. The general conclusion that the smooth-awned barley varieties have been more severely damaged by skinning has not been clearly substantiated by the data from the barleys grown at the stations cooperating in the

TABLE XI

TIME STEEPED IN WATER HELD AT 16° C. (60.8° F.) AND MOISTURE CONTENT OF BARLEY, AFTER STEEPING FOR THE FIVE VARIETIES OF BARLEY GROWN IN THE REGIONAL SERIES IN 1934, 1935, AND 1936. STEEP WATER CHANGED EVERY EIGHT HOURS

Variety	Year	A. Time steeped, hrs. B. Moisture content, %	Location where barley was grown														Average[3]
			Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg[1] or Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
			%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Oderbrucker	1934	A hrs.	—	34	—	—	36	34	41	—	32	35	—	35	35	—	34
	1934	B %	—	46.2	—	—	44.9	46.9	47.5	—	45.8	45.9	—	46.7	47.5	—	46.4
	1935	A hrs.	43	37	40	—	40	35	—	30	18	18	30	40	42	42	35
	1935	B %	49.7	44.9	47.9	—	44.6	45.4	—	47.8	51.9	45.7	49.2	46.7	46.8	47.0	47.3
	1936	A hrs.	—	42	47	45	41	32	36	32	15	—	—	41	34	41	37
	1936	B %	—	47.6	47.9	46.9	44.2	48.4	47.5	47.9	48.8	—	—	46.4	45.8	47.1	47.1
Wisconsin Barbless	1934	A hrs.	—	40	—	—	36	38	44	—	40	42	—	47	—	—	41
	1934	B %	—	46.2	—	—	45.5	45.9	47.0	—	45.8	45.6	—	46.0	—	—	46.0
	1935	A hrs.	47	46	48	—	48	48	—	46	24	—	42	47	45	47	44
	1935	B %	49.5	47.2	48.7	—	44.3	46.1	—	47.9	48.3	—	47.1	46.4	46.2	45.2	47.0
	1936	A hrs.	—	44	45	44	35	47	53	38	15	—	—	60	45	41	42
	1936	B %	—	47.5	47.1	47.3	47.7	48.4	49.0	47.5	47.9	—	—	47.3	46.2	46.0	47.5
Velvet	1934	A hrs.	—	38	—	—	32	34	41	—	32	38	—	40	41	—	37
	1934	B %	—	46.9	—	—	44.9	46.7	47.3	—	46.9	46.0	—	45.9	44.9	—	46.2
	1935	A hrs.	40	37	40	—	42	43	—	37	20	24	33	44	30	—	35
	1935	B %	49.9	45.6	48.0	—	45.6	45.1	—	47.2	49.6	48.6	47.8	47.2	43.0	—	47.0
	1936	A hrs.	—	43	47	47	35	35	48	38	19	—	—	48	35	32	39
	1936	B %	—	47.2	47.5	47.5	46.6	46.9	49.4	46.8	48.1	—	—	46.4	45.9	46.6	47.2
Manchuria	1934	A hrs.	—	32	—	—	28	30	40	—	38	34	—	37	38	—	35
	1934	B %	—	46.2	—	—	45.0	46.9	47.3	—	45.8	46.9	—	45.6	47.9	—	46.4
	1935	A hrs.	32	30	40	—	38	30	—	30	19	22	21	37	29	42	31
	1935	B %	49.5	46.9	49.1	—	44.1	45.1	—	47.6	49.5	49.4	45.6	45.3	44.3	46.4	46.9
	1936	A hrs.	—	38	42	44	33	32	42	32	19	—	—	41	32	32	35
	1936	B %	—	48.0	47.7	46.4	48.2	49.3[2]	48.3	47.7	50.5	—	—	47.3	48.0	47.5	48.1
Trebi	1934	A hrs.	—	48	—	—	36	38	44	—	60	50	—	50	53	—	47
	1934	B %	—	46.7	—	—	44.7	46.0	46.7	—	47.4	47.0	—	45.6	47.9	—	46.5
	1935	A hrs.	42	46	48	—	48	48	—	37	30	—	37	46	47	—	43
	1935	B %	51.1	46.9	47.8	—	46.2	47.9	—	48.5	47.3	—	48.0	45.7	47.9	—	47.7
	1936	A hrs.	—	41	62	66	44	35	69	43	29	—	—	47	47	—	48
	1936	B %	—	44.3	46.9	47.7	47.3	47.5	49.3	47.5	49.6	—	—	46.6	47.1	—	47.4

[1] Barleys grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) substituted for Manchuria (N. Dak. 2121) in Waseca series in 1936.
[3] Average for all stations; see Table XXIII for comparable averages.

regional barley studies. These results would indicate that with careful threshing varieties differ only slightly in damage from skinning and breaking, although under farm and industrial handling the general survey data obtained in another study show that more skinning occurs in the smooth-awned barleys. In 1936, however, records obtained from over 800 farm samples of Wisconsin Barbless and Oderbrucker

TABLE XII

Moisture Content of Green Malt at the End of the Germination Period for the Five Varieties of Barley Grown in the Regional Series in 1934, 1935, and 1936

Variety	Year	Location where barley was grown														Average[3]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg[1] or Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Oderbrucker	1934	—	52.4	—	—	53.2	51.2	48.8	—	52.0	50.4	—	49.5	50.8	—	51.0
	1935	46.3	46.1	45.7	—	45.2	46.2	—	49.1	51.1	44.9	44.0	44.3	44.2	48.5	46.3
	1936	—	45.4	47.7	45.3	48.6	46.5	46.6	45.6	47.2	—	—	48.6	46.7	48.0	46.9
Wisconsin Barbless	1934	—	49.9	—	—	52.9	50.3	48.6	—	51.4	50.9	—	51.0	—	—	50.7
	1935	44.6	46.2	45.9	—	46.7	45.8	—	46.8	44.0	—	43.3	43.3	43.0	43.3	44.8
	1936	—	46.4	44.5	47.4	45.4	44.1	47.1	46.6	46.5	—	—	45.1	46.0	45.7	45.9
Velvet	1934	—	50.7	—	—	52.0	50.5	48.9	—	51.3	50.7	—	49.9	51.3	—	50.7
	1935	47.4	45.8	46.4	—	47.7	46.3	—	47.3	47.1	45.8	43.9	45.4	44.5	—	46.1
	1936	—	45.4	46.1	44.6	46.2	45.3	46.4	47.6	45.6	—	—	44.7	46.8	44.1	45.7
Manchuria	1934	—	52.1	—	—	54.0	52.7	49.2	—	51.1	52.5	—	50.9	50.7	—	51.6
	1935	47.5	46.0	49.1	—	45.8	46.7	—	48.2	48.0	46.5	44.6	45.0	44.2	43.5	46.3
	1936	—	45.6	46.0	46.0	46.1[2]	48.2	46.7	46.9	47.3	—	—	48.4	45.2	51.3	47.1
Trebi	1934	—	50.1	—	—	52.4	51.2	48.1	—	49.9	49.4	—	49.4	49.1	—	49.9
	1935	46.9	45.9	49.0	—	47.9	44.5	—	48.1	45.6	—	45.9	45.0	43.4	—	46.2
	1936	—	48.7	44.9	44.8	44.7	44.7	45.4	44.7	49.0	—	—	45.1	45.9	—	45.8

[1] Barley grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) substituted for Manchuria (N. Dak. 2121) in Waseca series in 1936.
[3] Average for all stations; see Table XXIII for comparable averages.

TABLE XIII

Recovery of Malt from Barley on the Dry Basis for the Five Varieties of Barley Grown in the Regional Series in 1934, 1935, and 1936

Variety	Year	Location where barley was grown														Average[3]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg[1] or Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Oderbrucker	1934	—	85.8	—	—	83.7	88.3	90.4	—	86.5	88.8	—	90.1	88.4	—	87.8
	1935	88.5	85.9	83.2	—	88.0	84.6	—	78.8	79.5	85.6	83.5	91.4	90.4	83.4	85.2
	1936	—	90.2	87.6	90.4	85.7	87.7	89.4	88.9	86.6	—	—	85.9	87.9	84.6	87.7
Wisconsin Barbless	1934	—	89.5	—	—	84.1	89.3	90.4	—	87.9	88.2	—	89.1	—	—	88.4
	1935	85.4	89.8	86.5	—	88.3	90.2	—	85.4	87.8	—	91.7	88.4	86.5	86.6	87.9
	1936	—	92.6	90.8	91.9	90.5	90.5	87.7	89.5	88.5	—	—	89.8	89.7	88.4	90.0
Velvet	1934	—	88.9	—	—	84.7	88.4	90.0	—	87.5	88.0	—	90.0	87.4	—	88.1
	1935	85.1	85.2	87.6	—	89.0	86.7	—	81.9	83.9	86.6	89.4	91.0	84.6	—	86.4
	1936	—	89.4	89.7	91.0	89.5	89.2	86.8	87.9	90.9	—	—	91.3	87.3	90.1	89.4
Manchuria	1934	—	86.0	—	—	82.3	81.3	88.8	—	86.5	84.9	—	88.8	88.6	—	85.9
	1935	84.1	86.5	83.7	—	87.0	85.2	—	79.5	80.0	86.2	90.3	88.9	86.7	88.0	85.5
	1936	—	89.8	89.6	89.6	90.9	87.3[2]	88.7	88.8	89.1	—	—	86.3	88.3	86.1	88.6
Trebi	1934	—	90.1	—	—	84.1	89.5	91.6	—	90.3	90.4	—	91.3	91.4	—	89.8
	1935	90.0	89.7	86.2	—	85.4	94.6	—	83.9	85.0	—	86.8	89.2	88.2	—	87.9
	1936	—	88.6	91.0	90.9	92.2	90.2	90.8	90.7	88.5	—	—	92.5	89.1	—	90.4

[1] Barley grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) was substituted for Manchuria (N. Dak. 2121) in the Waseca series in 1936.
[3] Average for all stations; see Table XXIII for comparable averages.

TABLE XIV

Ash Content of Five Varieties of Barley Grown in the Regional Series in 1934, 1935, and 1936

Variety	Year	Location where barley was grown													Average[3]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg[1] or Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Oderbrucker	1934	—	2.03	—	—	2.60	2.65	2.62	—	2.77	2.49	—	2.41	2.32	—	2.49
	1935	4.34	2.97	3.15	—	3.25	3.13	—	3.40[1]	3.64	3.20	3.31	2.80	2.57	2.73	3.21
	1936	—	2.70	2.88	3.14	2.82	2.76	2.95	3.10[1]	2.96	—	—	2.90	2.68	2.91	2.89
Wisconsin Barbless	1934	—	1.73	—	—	2.74	2.59	2.55	—	2.54	2.35	—	2.30	—	—	2.40
	1935	3.12	2.79	2.97	—	3.10	3.01	—	3.10	3.19	3.17	3.07	2.63	2.57	2.80	2.96
	1936	—	2.43	2.86	2.94	3.07	2.69	2.94	3.00	3.01	—	—	2.85	2.70	2.81	2.85
Velvet	1934	—	1.86	—	—	2.40	2.62	2.56	—	2.54	2.34	—	2.37	2.22	—	2.36
	1935	3.43	2.95	3.22	—	3.43	3.25	—	3.65	3.61	3.53	3.34	2.77	2.42	—	3.22
	1936	—	2.99	2.87	3.07	2.99	2.62	2.83	3.00	2.74	—	—	2.85	2.61	2.95	2.91
Manchuria	1934	—	1.72	—	—	2.31	2.47	2.44	—	2.55	2.41	—	2.40	2.27	—	2.32
	1935	3.15	3.11	3.32	—	3.36	3.37	—	3.40	3.66	3.59	3.41	2.83	2.58	2.89	3.22
	1936	—	2.78	2.81	2.99	2.91	2.56[2]	2.84	3.10	2.78	—	—	2.98	2.74	2.91	2.85
Trebi	1934	—	1.86	—	—	2.12	2.37	2.63	—	1.94	2.10	—	2.07	2.07	—	2.14
	1935	3.25	2.92	2.92	—	3.08	2.91	—	3.15	3.36	3.15	3.14	2.59	2.57	—	3.00
	1936	—	2.46	2.74	2.74	2.81	2.38	2.85	2.80	2.58	—	—	2.93	2.68	—	2.70

[1] Barley grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) was substituted for Manchuria (N. Dak. 2121) in Waseca series in 1936.
[3] Average for all stations; see Table XXIII for comparable averages.

TABLE XV

Yield of Extract on the Dry Basis of Fine Grind Malt. Five Varieties of Barley Grown in the Regional Series for 1934, 1935, and 1936

Variety	Year	Location where barley was grown													Average[3]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg[1] or Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Oderbrucker	1934	—	71.4	—	—	71.0	71.4	72.6	—	72.0	70.0	—	72.8	70.9	—	71.5
	1935	73.2	74.6	75.6	—	76.0	74.2	—	71.0[1]	65.7	67.4	72.6	73.6	74.7	77.2	73.0
	1936	—	74.0	73.0	75.7	72.1	71.7	70.7	71.2[1]	6[illegible].8	—	—	73.3	74.5	77.2	72.6
Wisconsin Barbless	1934	—	69.9	—	—	67.9	68.5	70.9	—	71.2	67.8	—	71.4	—	—	69.7
	1935	71.3	72.4	74.2	—	74.2	72.4	—	71.0	63.8	—	71.8	72.3	75.0	76.6	72.3
	1936	—	69.1	70.4	73.4	68.4	70.3	68.8	68.7	62.6	—	—	72.9	72.9	74.8	70.2
Velvet	1934	—	70.7	—	—	69.5	69.2	71.4	—	72.4	70.5	—	74.0	69.6	—	70.9
	1935	71.9	78.8	76.0	—	76.1	75.2	—	72.6	63.4	68.0	73.4	72.3	76.0	—	72.4
	1936	—	73.3	72.6	75.8	72.0	70.7	70.9	71.6	66.8	—	—	71.6	75.8	75.3	72.4
Manchuria	1934	—	70.9	—	—	73.1	72.4	72.0	—	74.3	71.7	—	73.8	70.3	—	72.3
	1935	72.6	73.4	75.9	—	77.0	76.0	—	72.7	66.3	69.7	72.4	74.2	77.2	77.5	73.7
	1936	—	73.0	72.6	76.4	72.2	72.3[2]	73.1	71.5	67.0	—	—	74.9	75.4	75.6	73.1
Trebi	1934	—	73.6	—	—	69.3	69.3	73.7	—	73.9	72.5	—	74.7	70.8	—	72.2
	1935	71.9	75.0	77.1	—	77.2	74.4	—	70.9	66.5	—	72.4	74.9	75.5	—	73.6
	1936	—	69.9	74.9	76.9	73.1	72.8	71.9	71.9	66.0	—	—	72.6	73.7	—	72.4

[1] Barley grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) substituted for Manchuria (N. Dak. 2121) as latter not grown at Waseca with series in 1936.
[3] Average for all stations; see Table XXIII for comparable averages.

show less than 0.3% difference between the two varieties in skinning and breaking. The data on skinned and broken kernels are given in Table VII.

The percentage of hull in the barleys grown in 1936 was in general like that of 1934, though higher than in 1935. The differences in hull percentage for the three years were principally in the barleys grown at the stations in the upper Mississippi Valley area where the seasonal contrast of the three years was much greater than at the irrigated stations. The three varieties, Wisconsin Barbless, Velvet, and Trebi, have averaged slightly more than Oderbrucker and Manchuria in

TABLE XVI

TOTAL PROTEIN CONTENT OF THE FIVE VARIETIES OF BARLEY GROWN IN THE REGIONAL SERIES FOR 1934, 1935, AND 1936

Variety	Year	Location where barley was grown														Average[3]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg[1] or Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Oderbrucker	1934	—	—	—	—	20.08	—	17.15	—	17.97	—	—	16.61	—	—	17.95
	1935	14.49	14.05	14.18	—	15.53	14.36	—	16.16[1]	16.75	15.18	14.00	15.80	15.53	13.16	14.93
	1936	—	11.80	13.03	10.98	13.10	16.00	15.47	14.58[1]	16.69	—	—	15.47	15.25	13.62	14.18
Wisconsin Barbless	1934	—	—	—	—	19.68	—	15.84	—	17.65	—	—	15.56	—	—	17.18
	1935	14.08	13.88	13.03	—	12.64	14.27	—	15.41	16.00	14.64	13.34	14.80	14.23	12.70	14.08
	1936	—	13.56	12.51	10.57	12.89	12.66	13.74	13.44	15.74	—	—	14.43	13.73	14.37	13.42
Velvet	1934	—	—	—	—	20.02	—	16.84	—	17.15	—	—	15.03	—	—	17.26
	1935	14.70	15.59	13.47	—	13.31	13.53	—	15.55	16.49	14.70	14.02	14.55	14.93	—	14.62
	1936	—	11.90	13.00	11.58	13.59	16.56	15.52	14.43	16.34	—	—	14.61	14.18	15.12	14.26
Manchuria	1934	—	—	—	—	16.72	—	15.90	—	16.33	—	—	15.24	—	—	16.05
	1935	15.80	15.12	14.04	—	13.65	15.34	—	16.24	17.06	15.49	15.74	14.90	14.93	12.13	15.04
	1936	—	12.11	13.25	11.17	13.62	17.18[2]	14.43	14.49	15.10	—	—	14.52	13.68	14.18	13.97
Trebi	1934	—	—	—	—	17.34	—	14.12	—	14.33	—	—	13.34	—	—	14.78
	1935	15.09	12.16	11.39	—	11.26	13.07	—	16.00	15.74	15.96	13.80	13.59	14.42	—	13.86
	1936	—	14.67	11.42	9.70	11.45	15.25	13.47	12.98	15.07	—	—	14.46	12.98	—	13.14

[1] Barley grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) substituted for Manchuria (N. Dak. 2121), as latter not grown at Waseca with series in 1936.
[3] Average for all stations; see Table XXIII for comparable averages.

hull content in the comparative three-year average (Tables VIII and XXIII).

The endosperm texture of the barleys grown at the various stations in 1936 was decidedly hard although the starch mass became mellow after steeping and drying. The starch mass of the dry kernels was nearly as hard as in the barleys grown in 1934. Steeping the barley for 24 to 30 hours at 16° C. (60.8° F.) followed by drying resulted in an average mellowness slightly better than that obtained with the relatively mellow barley of 1935 and much better than in 1934 (Tables IX and XXIII). The Trebi variety was lowest in mellow kernels

TABLE XVII

TOTAL PROTEIN CONTENT OF THE MALTS FROM THE FIVE VARIETIES OF BARLEY GROWN IN THE REGIONAL SERIES IN 1934, 1935, AND 1936

Variety	Year	Location where barley was grown														Average[4]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg[1] or Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort, Collins Colo.	Davis, Cal.	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Oderbrucker	1934	——	15.53	——	——	20.73[3]	19.03	16.09[3]	——	17.72[3]	16.94	——	16.40[3]	17.15	——	17.45[3]
	1935	14.18	13.67	14.31	——	13.22	14.09	——	17.12	17.24	14.36	13.68	15.61	14.84	12.89	14.60
	1936	——	11.55	12.43	10.52	12.98	15.53	15.38	14.49	17.93	——	——	15.28	14.61	13.72	14.04
Wisconsin Barbless	1934	——	14.44	——	——	19.84	18.13	15.40	——	15.87	16.34	——	15.55	——	——	16.51
	1935	13.62	13.35	12.57	——	12.24	13.62	——	14.24	15.44	——	12.79	14.43	13.59	12.16	13.46
	1936	——	13.29	11.70	9.64	12.35	14.70	13.61	13.03	15.13	——	——	14.34	13.38	14.12	13.21
Velvet	1934	——	15.54	——	——	20.27	18.96	16.75	——	17.54	16.18	——	14.00	16.90	——	17.02
	1935	14.15	15.03	13.04	——	12.64	13.06	——	15.47	16.39	14.22	13.90	14.08	14.67	——	14.24
	1936	——	11.35	12.70	11.01	12.63	15.96	15.13	13.99	16.09	——	——	14.37	13.83	15.16	13.84
Manchuria	1934	——	17.43	——	——	17.80	17.22	15.87	——	15.68	15.71	——	15.12	16.33	——	16.39
	1935	15.53	14.71	13.80	——	13.56	14.84	——	15.28	16.82	15.81	15.87	14.12	14.67	11.46	14.70
	1936	——	12.11	13.32	10.83	13.13	16.00[2]	14.12	14.31	15.71	——	——	14.02	15.28	14.02	13.90
Trebi	1934	——	12.91	——	——	18.09	16.43	14.30	——	13.56	13.22	——	13.22	15.81	——	14.69
	1935	14.64	11.58	11.08	——	10.88	13.16	——	15.47	15.75	——	13.64	12.60	14.58	——	13.34
	1936	——	14.37	11.29	9.17	10.83	15.44	13.64	12.63	16.00	——	——	14.84	12.56	——	13.08

[1] Barley grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) substituted for Manchuria (N. Dak. 2121) as latter not grown at Waseca with series in 1936.
[3] Protein content of the four malts from barleys in which protein was determined in 1934 is as follows: Oderbrucker, 17.73, Wisconsin Barbless, 16.66, Velvet, 17.14, Manchuria, 16.11, and Trebi, 14 79%.
[4] Average for all stations; see Table XXIII for comparable averages.

both before and after steeping. The seasonal effect on mellowness was seemingly greater than either station or variety although the influence of the latter was very significant. Modification of the endosperm mass in malting was very good in all varieties except Trebi, and Wisconsin Barbless in 1934.

The average rate of water absorption in the 1936 crop was somewhat slower for Oderbrucker and Trebi and slightly faster for Velvet, Manchuria, and Wisconsin Barbless than in the 1935 crop. Over the

TABLE XVIII

SOLUBLE NITROGEN IN THE WORT EXPRESSED AS PROTEIN (N. × 6.25) FOR THE MALTS FROM THE FIVE VARIETIES OF BARLEY GROWN IN THE REGIONAL SERIES IN 1934, 1935, AND 1936

Variety	Year	Location where barley was grown														Average[3]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg[1] or Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Oderbrucker	1934	—	5.06	—	—	7.28	6.31	5.62	—	5.84	5.31	—	4.68	5.12	—	5.65
	1935	5.06	4.82	5.12	—	4.75	5.12	—	7.12	7.25	4.50	5.97	4.28	4.69	4.62	5.27
	1936	—	3.79	4.44	3.94	4.84	5.58	5.35	5.21	5.55	—	—	5.04	5.23	5.25	4.93
Wisconsin Barbless	1934	—	3.47	—	—	5.37	4.65	4.03	—	4.25	3.93	—	3.47	—	—	4.17
	1935	4.12	4.03	4.00	—	3.75	3.87	—	4.65	4.62	—	4.03	3.06	3.53	3.18	3.89
	1936	—	3.57	3.37	3.19	3.71	3.83	3.90	3.55	4.23	—	—	3.25	3.91	3.85	3.67
Velvet	1934	—	4.71	—	—	6.25	6.03	5.19	—	5.53	4.78	—	4.25	4.78	—	5.19
	1935	5.97	5.00	4.97	—	4.97	4.92	—	6.19	6.44	6.16	5.44	3.31	4.88	—	5.29
	1936	—	4.05	4.60	4.23	4.55	5.31	5.24	5.02	5.39	—	—	3.49	5.01	4.94	4.71
Manchuria	1934	—	5.09	—	—	6.22	5.81	5.47	—	5.28	4.59	—	4.24	4.72	—	5.18
	1935	6.78	5.53	4.81	—	5.62	5.97	—	7.57	7.12	7.28	6.90	3.93	5.25	3.93	5.89
	1936	—	4.18	4.60	3.98	4.68	5.68[2]	5.13	4.90	7.35	—	—	5.03	4.43	5.47	5.04
Trebi	1934	—	3.62	—	—	4.81	4.47	3.93	—	3.78	3.34	—	3.18	3.53	—	3.83
	1935	5.53	3.90	4.18	—	3.78	2.94	—	5.47	4.85	—	4.65	4.00	4.15	—	4.34
	1936	—	3.99	3.27	3.02	3.35	4.74	3.83	3.65	4.90	—	—	3.49	3.54	—	3.78

[1] Barley grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.
[2] Manchuria (Minn. 184) was substituted for Manchuria (N. Dak. 2121), in the Waseca series in 1936 as the latter was not grown.
[3] Average for all stations; see Table XXIII for comparable averages.

three-year period at six comparable stations Trebi required the longest time for absorption, with Wisconsin Barbless next, and Velvet, Oderbrucker and Manchuria following in the order given. The Wisconsin Barbless samples grown at the stations in the upper Mississippi Valley area in 1936 reached the same average moisture content as in 1935 with an average of six hours less time in the steep than in 1935. The immaturity of the grain and the lower kernel weight were largely responsible for this. The other varieties showed this seasonal influence on water absorption at only part of the stations (Table X).

The barleys were steeped and malted at approximately the same

moisture content as in 1935. The average moisture content out of the steep for 1934 was 46.5%, for 1935, 47.2%, and for 1936, 47.5%. The average moisture content at the end of the germination period for 1935 was 45.9%, and for 1936, 46.3% (Tables XI and XII). The 1934 barleys were grown at a higher moisture content especially toward the

TABLE XIX

THE COMPARISON OF AVERAGE NITROGEN MODIFICATION IN THE WORTS, AVERAGE KERNEL WEIGHT OF MALT, AVERAGE RECOVERY OF MALT FROM BARLEY AND AVERAGE DIASTATIC POWER OF MALTS FOR THE FIVE VARIETIES OF BARLEY GROWN IN THE REGIONAL SERIES IN 1934, 1935, AND 1936

Variety of barley	Year grown	Total samples averaged,[1] number	Kernel weight of malt, dry basis, in mg.	Malt nitrogen, %	Soluble nitrogen in wort, %	Soluble nitrogen as % of malt nitrogen, %	Recovery of malt from barley, dry basis, %	Diastatic power of malt, °L.
Oderbrucker	1934	8	25.6	2.79	.904	32.40	87.8	153.1
	1935	12	22.6	2.34	.843	36.03	85.2	182.1
	1936	11	23.0	2.25	.789	35.07	87.7	191.9
3 year average		31	23.7	2.46	.845	34.51	86.9	175.7
Wisconsin Barbless	1934	7	26.0	2.64	.667	25.27	88.4	77.6
	1935	11	25.0	2.15	.622	28.93	87.9	133.8
	1936	11	24.2	2.11	.588	28.01	90.0	117.6
3 year average		29	25.1	2.30	.626	27.40	88.8	109.7
Velvet	1934	8	24.6	2.72	.830	30.51	88.1	105.3
	1935	11	24.6	2.28	.846	37.11	86.4	165.4
	1936	11	23.1	2.22	.755	34.26	89.4	152.7
3 year average		30	24.1	2.40	.810	33.96	88.0	141.1
Manchuria	1934	8	22.9	2.62	.829	36.65	85.9	124.7
	1935	12	21.2	2.35	.942	40.09	85.5	190.8
	1936	11	21.6	2.32	.778	35.04	88.6	194.5
3 year average		31	21.9	2.40	.850	37.26	86.7	170.0
Trebi	1934	8	32.6	2.35	.613	26.08	89.8	75.9
	1935	10	28.7	2.13	.694	32.58	87.9	143.5
	1936	10	29.6	2.09	.605	29.06	90.4	158.3
3 year average		28	30.3	2.19	.637	29.24	89.4	125.9

[1] Average of all malts for each year, therefore not comparable averages between years.

end of the germination period. The writers believe the moistures used have been high enough to give satisfactory results with all five varieties and thus have avoided the use of different moistures for each variety in a comparative study of this type. The physiological studies on moisture in relation to malting indicate that Wisconsin Barbless is more tolerant of higher moisture content in malting than Oderbrucker.

The average recovery of malt from barley was slightly higher in 1936 than in 1935, and considerably more than in 1934. The recovery from the Oderbrucker variety from three stations was lower than in 1935. The data on malt recovery are given in Tables XIII and XXIII. Years, varieties and stations affect malt recovery in descending order.

The percentage of ash in the 1936 barleys from all stations except the three western locations was lower than in 1935. The influence of the season on ash content was greater than was the location where grown or the variety. The data on ash content for the three years are given in Tables XIV and XXIII.

TABLE XX

THE COMPARISON OF AVERAGE NITROGEN MODIFICATION IN THE WORTS, AND CERTAIN PHYSICAL AND CHEMICAL FACTORS OF BARLEY AND MALT FOR THE FIVE VARIETIES OF BARLEY GROWN IN THE REGIONAL SERIES IN 1936

	Barley variety				
	Oderbrucker	Wisconsin Barbless	Velvet	Manchuria	Trebi
Total number of malts analyzed	11	11	11	11	10
Kernel weight of barley, dry basis, in mg.	26.0	26.7	25.8	24.7	33.3
Nitrogen in barley, %	2.27	2.09	2.28	2.19	2.10
Index of mellowness of dry barley, %	41.3	41.8	43.3	45.2	27.1
Index of mellowness of barley steeped and dried, %	95.2	96.8	94.3	95.7	89.1
Kernel weight of malt, dry basis, in mg.	23.0	24.2	23.2	21.6	29.6
Nitrogen in malt, %	2.25	2.11	2.22	2.32	2.09
Soluble nitrogen in wort, %	.789	.588	.755	.778	.605
Soluble nitrogen as % of malt N., %	32.25	28.01	34.26	35.04	29.06
Permanently soluble nitrogen in wort, %	.748	.564	.724	.748	.574
Permanently soluble nitrogen as % of malt N., %	33.27	26.73	32.61	33.99	27.59
Permanently soluble nitrogen as % of wort N., %	94.8	95.9	95.9	95.4	94.9
Formol nitrogen in wort, %	.151	.112	.150	.158	.104
Formol nitrogen as % of malt N., %	6.73	5.31	6.76	6.81	4.98
Formol nitrogen as % of wort N., %	19.11	17.36	19.79	20.32	17.17
Formol nitrogen as % of permanently soluble N., %	20.24	19.86	20.72	20.70	18.09
Recovery of malt from barley, dry basis, %	87.7	90.0	89.4	88.6	90.4
Index of mellowness of malt, %	97.0	98.7	95.0	97.6	91.6
Diastatic power of malt, °L.	192	118	153	194	158

The extract yield of the malts was low especially in barleys grown at most of the stations in the upper Mississippi Valley. The average extract yield for all stations was significantly lower than in 1935 for the Wisconsin Barbless and Trebi varieties and about the same as in 1935 for Oderbrucker, Velvet, and Manchuria. The average extract yield for the malts from the six comparable stations was lower than in the malts from either of the previous seasons (Table XXIII). The barleys grown at one station in the north-central area, namely DeKalb, Illinois, produced malts very high in extract content. In general the malts from Wisconsin Barbless barleys grown at the stations in the upper Mississippi Valley were low in extract. The relative position of the varieties on the basis of average extract yield from the malts shifted somewhat from the 1934 and 1935 rankings in that Oderbrucker

TABLE XXI

COMPARISON OF NITROGEN MODIFICATION IN THE LABORATORY WORTS AND KERNEL WEIGHT OF MALT, RECOVERY OF MALT FROM BARLEY, DIASTATIC POWER OF THE MALTS AND ENDOSPERM CHARACTER OF THE MALTS FROM THE BARLEY VARIETIES GROWN IN THE REGIONAL SERIES IN 1936

Variety and location where barley was grown	Moisture content of malt	Kernel weight of malt, dry basis	Nitrogen in malt	Soluble nitrogen in wort	Soluble nitrogen as % of malt N	Permanently soluble nitrogen in wort	Permanently soluble nitrogen as % of malt N	Permanently soluble nitrogen as % of wort N	Formol nitrogen in wort	Formol N as % of malt N	Formol N as % of wort N	Formol N as % of permanent soluble N	Recovery of malt from barley, dry basis	Diastatic power of malt	Endosperm character of malt. Index of mellowness
	%	*Mg.*	%	%	%	%	%	%	%	%	%	%	%	°*L.*	%
Oderbrucker															
East Lansing, Mich.	5.2	26.4	1.85	.606	32.76	.579	31.29	95.5	.113	6.11	18.64	19.52	90.2	149	100
Urbana, Ill.	4.1	24.7	1.99	.712	35.78	.679	34.12	95.4	.135	6.79	18.96	19.88	87.6	168	93.5
DeKalb, Ill.	4.0	25.7	1.68	.631	37.56	.603	35.89	95.6	.111	6.61	17.59	18.41	90.4	113	98.0
Madison, Wis.	5.6	20.7	2.08	.775	37.26	.743	35.72	95.9	.140	6.73	18.06	18.84	85.7	182	98.5
Waseca, Minn.	4.5	20.8	2.49	.893	35.86	.845	33.94	94.6	.178	7.15	19.93	21.06	87.7	212	96.0
Kanawha, Ia.	4.2	20.7	2.46	.856	34.80	.814	33.09	95.1	.154	6.26	17.99	18.92	89.4	207	98.0
Ames, Ia.	4.2	20.4	2.32	.834	35.95	.797	34.35	95.6	.158	6.81	18.94	19.82	88.9	197	97.0
Brookings, S. D.	3.3	16.1	2.87	.888	30.94	.839	29.23	94.5	.188	6.55	21.17	22.40	86.6	182	98.5
Bozeman, Mont.	5.6	26.7	2.45	.807	32.94	.751	30.65	93.1	.150	6.12	18.59	19.97	85.9	272	96.5
Fort Collins, Col.	4.8	25.0	2.34	.836	35.73	.789	33.72	94.4	.170	7.26	20.33	21.55	87.9	215	95.0
Davis, Cal.	6.4	26.4	2.20	.839	38.14	.789	35.86	94.0	.168	7.64	20.02	21.29	84.6	214	96.5
Oderbrucker, average	4.7	23.0	2.25	.789	35.25	.748	33.27	94.8	.151	6.73	19.11	20.24	87.7	192	97.0
Wisconsin Barbless															
East Lansing, Mich.	4.5	32.4	2.13	.571	26.81	.550	25.82	96.3	.094	4.41	16.46	17.09	92.6	119	100
Urbana, Ill.	4.1	23.4	1.87	.540	28.88	.515	27.54	95.4	.088	4.71	16.30	17.09	90.8	116	100
DeKalb, Ill.	4.4	22.9	1.54	.512	33.25	.491	31.88	95.9	.089	5.78	17.38	18.13	91.9	74	100
Madison, Wis.	4.4	21.2	1.98	.594	30.00	.575	29.04	96.8	.117	5.91	19.70	20.35	90.5	89	97.5
Waseca, Minn.	4.0	20.5	2.36	.613	25.97	.587	24.87	95.8	.098	4.15	15.99	16.69	90.5	110	100
Kanawha, Ia.	4.1	22.3	2.18	.626	28.72	.603	27.66	96.3	.106	4.86	16.93	17.58	87.7	121	100
Ames, Ia.	5.0	21.6	2.09	.568	27.18	.542	25.93	95.4	.099	4.74	17.43	18.27	89.5	124	100
Brookings, S. D.	3.5	16.3	2.42	.679	28.06	.648	26.78	95.4	.139	5.74	20.47	21.45	88.5	104	100
Bozeman, Mont.	5.2	31.9	2.30	.521	22.65	.497	21.61	95.4	.081	3.52	15.55	16.30	89.8	155	89.0
Fort Collins, Col.	5.3	24.5	2.14	.627	29.30	.603	28.18	96.2	.108	5.05	17.22	17.91	89.7	129	100
Davis, Cal.	5.7	29.5	2.26	.617	27.30	.594	26.28	96.3	.108	4.78	17.50	18.18	88.4	153	99.0
Wisconsin Barbless, average	4.6	24.2	2.11	.588	28.01	.564	26.73	95.9	.112	5.31	17.36	19.86	90.0	118	98.7

TABLE XXI—*Continued*

Variety and location where barley was grown	Moisture content of malt	Kernel weight of malt, dry basis	Nitrogen in malt	Soluble nitrogen in wort	Soluble nitrogen as % of malt N	Permanently soluble nitrogen in wort	Permanently soluble nitrogen as % of malt N	Permanently soluble nitrogen as % of wort N	Formol nitrogen in wort	Formol N as % of malt N	Formol N as % of wort N	Formol N as % of permanent soluble N	Recovery of malt from barley, dry basis	Diastatic power of malt	Endosperm character of malt. Index of mellowness
	%	*Mg.*	%	%	%	%	%	%	%	%	%	%	%	°*L.*	%
Velvet															
East Lansing, Mich.	5.1	24.5	1.82	.649	35.66	.626	34.40	96.5	.123	6.76	18.95	19.65	89.4	118	100
Urbana, Ill.	4.3	23.5	2.03	.737	36.31	.702	34.58	95.2	.140	6.90	19.00	19.94	89.7	150	100
DeKalb, Ill.	4.4	25.0	1.76	.679	38.58	.655	37.22	96.5	.135	7.67	19.88	20.61	91.0	95	98.0
Madison, Wis.	4.6	20.4	2.02	.728	36.04	.703	34.80	96.6	.154	7.62	21.15	21.91	89.5	123	99.5
Waseca, Minn.	4.4	22.1	2.56	.851	33.24	.818	31.95	96.1	.175	6.84	20.56	21.39	89.2	171	90.0
Kanawha, Ia.	4.2	20.7	2.42	.839	34.67	.808	33.39	96.3	.163	6.73	19.42	20.17	86.8	165	90.0
Ames, Ia.	5.2	22.1	2.24	.804	35.89	.769	34.34	95.6	.155	6.92	19.28	20.16	87.9	170	97.0
Brookings, S. D.	4.0	17.4	2.58	.863	33.45	.832	32.25	96.4	.183	7.09	21.21	22.00	90.9	160	98.0
Bozeman, Mont.	5.0	29.0	2.30	.559	24.30	.530	23.04	94.8	.089	3.87	15.92	16.79	91.3	162	80.5
Fort Collins, Col.	5.0	24.3	2.22	.802	36.13	.770	34.68	96.0	.176	7.93	21.95	22.86	87.3	175	94.5
Davis, Cal.	5.3	25.8	2.43	.791	32.55	.749	30.82	94.7	.161	6.63	20.35	21.50	90.1	191	98.0
Velvet, average	4.7	23.3	2.22	.755	34.26	.724	32.61	95.9	.150	6.76	19.79	20.72	89.4	153	95.0
Manchuria															
East Lansing, Mich.	5.2	23.3	1.94	.670	34.54	.642	33.09	95.8	.118	6.08	17.61	18.38	89.8	158	96.5
Urbana, Ill.	4.9	22.3	2.13	.733	34.41	.702	32.96	95.8	.136	6.38	18.55	19.37	89.6	207	99.0
DeKalb, Ill.	4.9	23.3	1.73	.639	36.94	.613	35.43	95.9	.118	6.82	18.47	19.25	89.6	118	100
Madison, Wis.	4.4	21.3	2.10	.750	35.71	.722	34.38	96.3	.154	7.33	20.53	21.33	90.9	153	98.5
Waseca, Minn.	5.0	19.6	2.56	.905	35.35	.865	33.79	95.6	.188	7.34	20.77	21.73	87.3	207	93.5
Kanawha, Ia.	4.9	21.2	2.26	.821	36.33	.780	34.51	95.0	.155	6.86	18.88	19.87	88.7	205	98.0
Ames, Ia.	4.3	20.2	2.29	.790	34.50	.755	32.97	95.6	.164	7.16	20.76	21.72	88.8	199	99.0
Brookings, S. D.	4.0	13.8	2.52	.857	34.01	.810	32.14	94.5	.177	7.02	20.65	21.85	89.1	210	98.5
Bozeman, Mont.	6.2	25.7	2.25	.804	35.73	.755	33.56	93.9	.155	6.89	19.28	20.53	86.3	259	98.5
Fort Collins, Col.	4.9	21.7	2.45	.710	28.97	—	—	—	.185	7.55	26.06	—	88.3	222	98.0
Davis, Cal.	5.1	25.3	2.25	.876	38.93	.835	37.11	95.3	.192	8.53	21.92	22.99	86.1	202	94.0
Manchuria, average	4.9	21.6	2.23	.778	35.04	.748	33.99	95.4	.158	6.81	20.32	20.70	88.6	194	97.6

TABLE XXI—*Continued*

Variety and location where barley was grown	Moisture content of malt	Kernel weight of malt, dry basis	Nitrogen in malt	Soluble nitrogen in wort	Soluble nitrogen as % of malt N	Permanently soluble nitrogen in wort	Permanently soluble nitrogen as % of malt N	Permanently soluble nitrogen as % of wort N	Formol nitrogen in wort	Formol N as % of malt N	Formol N as % of wort N	Formol N as % of permanent soluble N	Recovery of malt from barley, dry basis	Diastatic power of malt	Endosperm character of malt. Index of mellowness
	%	*Mg.*	%	%	%	%	%	%	%	%	%	%	%	°L.	%
Trebi															
East Lansing, Mich.	5.7	28.5	2.30	.640	27.83	.604	26.26	94.4	.130	5.65	20.31	21.52	88.6	185	90.0
Urbana, Ill.	4.9	33.4	1.81	.524	28.95	.495	27.35	94.5	.081	4.47	15.45	16.36	91.0	151	93.0
DeKalb, Ill.	4.5	34.6	1.47	.483	32.86	.459	31.22	95.0	.084	5.71	17.39	18.30	90.9	88	98.0
Madison, Wis.	5.0	29.5	1.73	.536	30.98	.511	29.54	95.3	.099	5.72	18.47	19.37	92.2	103	98.5
Waseca, Minn.	4.7	27.3	2.47	.758	30.69	.717	29.03	94.5	.141	5.71	18.60	19.67	90.2	175	95.0
Kanawha, Ia.	4.6	28.7	2.19	.614	28.04	.583	26.62	94.9	.099	4.52	16.12	16.98	90.8	163	96.5
Ames, Ia.	5.2	29.3	2.02	.585	28.96	.561	27.77	95.9	.099	4.90	16.92	17.65	90.7	142	100
Brookings, S. D.	4.9	19.6	2.56	.784	30.63	.742	28.98	94.6	.136	5.31	17.35	18.33	88.5	222	95.5
Bozeman, Mont.	5.2	36.2	2.38	.559	23.49	.529	22.23	94.6	.081	3.40	14.49	15.31	92.5	189	74.0
Fort Collins, Col.	4.5	28.8	2.01	.567	28.21	.541	26.91	95.4	.094	4.68	16.57	17.37	89.1	165	76.0
Trebi, average	4.9	29.6	2.09	.605	29.06	.574	27.59	94.9	.104	4.98	17.17	18.09	90.4	158	91.6

yielded higher than Trebi. The data on yield of extract for the three years are given in Tables XV and XXIII.

The average protein content of barleys and malts from all stations was lower in 1936 than in either of the previous two years and averaged about the same as in 1935 for the six stations. This is somewhat contrary to expectations as in general the hot, dry weather and hastened maturity are considered likely to increase protein content. The

TABLE XXII

DIASTATIC POWER EXPRESSED IN DEGREES LINTNER OF MALTS FROM THE FIVE VARIETIES OF BARLEY GROWN IN THE REGIONAL SERIES IN 1934, 1935, AND 1936

Variety	Year	Location where barley was grown														Average[4]
		Columbus, Ohio	East Lansing, Mich.	Urbana, Ill.	DeKalb, Ill.	Madison, Wis.	Waseca, Minn.	Kanawha, Ia.	Emmetsburg[2] or Ames, Ia.	Brookings, S. D.	Fargo, N. D.	Lincoln, Neb.	Bozeman, Mont.	Fort Collins, Colo.	Davis, Cal.	
		°L.	°L.	°L.	°L.	°L.	°L.	°L.	°L.	°L.	°L.	°L.	°L.	°L.	°L.	°L.
Oderbrucker	1934[1]	—	142	—	—	152	184	109	—	164	167	—	167	140	—	153.1
	1935	175	145	211	—	175	172	—	212	229	140	192	205	191	138	182.1
	1936	—	149	168	113	182	212	207	197	182	—	—	272	215	214	191.9
Wisconsin Barbless	1934	—	51	—	—	107	81	57	—	73	97	—	77	—	—	77.6
	1935	139	130	152	—	124	149	—	152	151	—	117	114	129	115	133.8
	1936	—	119	116	74	89	110	121	124	104	—	—	155	129	153	117.6
Velvet	1934	—	76	—	—	135	152	—	—	94	93	—	96	91	—	105.3
	1935	177	160	164	—	158	152	—	144	215	179	148	155	167	—	165.4
	1936	—	118	150	95	123	171	165	170	160	—	—	162	175	191	152.7
Manchuria	1934	—	143	—	—	133	154	—	—	137	133	—	77	96	—	124.7
	1935	177	164	205	—	187	184	—	217	220	208	207	165	208	148	190.8
	1936	—	158	207	118	153	207[3]	205	199	210	—	—	259	222	202	194.5
Trebi	1934	—	61	—	—	78	93	71	—	70	69	—	78	87	—	75.9
	1935	184	123	127	—	131	140	—	131	180	—	135	149	135	—	143.5
	1936	—	185	151	88	103	175	163	142	222	—	—	189	165	—	158.3

[1] The malts produced in the 1934 studies were dried below 4% moisture which reduced the diastatic power below the values for the latter two years.

[2] Barley grown at Emmetsburg in 1935, and at Ames, Iowa, in 1936.

[3] Manchuria (Minn. 184) was substituted for Manchuria (N. Dak. 2121) in the Waseca series in 1936 as the latter was not grown.

[4] Average for all stations; see Table XXIII for comparable averages.

protein content of the barleys and malts from the stations in the north-central area was lower with the exception of the varieties grown at Waseca, Minnesota, where all the barleys except Wisconsin Barbless were higher than in 1935. Likewise three of the four varieties grown at Davis, California, were higher than in 1935. The relative order of the varieties has shifted significantly in all three years, with Trebi and Wisconsin Barbless ranking the lowest each year except 1934, when Manchuria was lower than Wisconsin Barbless. The data on protein content are given in Tables XVI, XVII and XXIII.

TABLE XXIII

AVERAGES OF DATA ON BARLEYS AND MALTS FOR THE FIVE BARLEY VARIETIES GROWN IN THE REGIONAL SERIES IN 1934, 1935, AND 1936 AT EAST LANSING, MICHIGAN, MADISON, WISCONSIN, WASECA, MINNESOTA, KANAWHA, IOWA, BROOKINGS, SOUTH DAKOTA, AND BOZEMAN, MONTANA

Variety	Year	Yield of barley per acre	Bushel weight of barley, dry basis	Bushel weight of malt, 4% basis	Kernel weight of barley, dry basis	Kernel weight of malt, dry basis	Skinned and broken kernels	Weight of hull of barley	Index [2] of mellowness of endosperm of dry barley A	Index [1] of mellowness of endosperm of barley steeped 24 to 30 hrs. B	Index of mellowness of malt C	Estimated time steeped to reach 46% moisture	Time steeped	Moisture content steeped barley	Moisture content of sprouted barley	Recovery of malt from barley dry basis	Ash content of barley	Yield of extract of malt, dry basis	Total protein in barley N. × 6.25	Total protein in malt N. × 6.25	Soluble nitrogen in wort as protein N. × 6.25	Diastatic power of malt
		Bu.	*Lbs.*	*Lbs.*	*Mg.*	*Mg.*	%	%	%	%	%	*Hrs.*	*Hrs.*	%	%	%	%	%	%	%	%	°*L.*
Oderbrucker	1934	21.6	40.3	36.5	28.2[3]	26.4	7.0	12.4	24.7	53.4	85.6	33.7	35.3	46.3	51.2	87.5	2.51	71.8	17.95[4]	17.59	5.79	150.5
	1935	36.3	38.6	35.3	25.5	22.0	2.7	11.5	67.5	95.4	94.3	33.9	33.3	46.9	47.0	84.7	3.20	74.2	14.65	15.16	5.56	189.7
	1936	31.6	39.4	34.2	24.7	21.9	4.6	13.2	36.8	97.6	97.9	31.4	34.5	47.1	47.1	87.6	2.85	71.1	14.75	14.77	5.02	200.7
3-year average		29.9	39.4	35.3	26.1	23.4	4.8	12.4	43.0	82.1	92.6	33.0	34.4	46.8	48.4	86.6	2.85	72.4	15.78	15.84	5.46	180.3
Wisconsin Barbless	1934	34.1	39.2	36.5	29.2[3]	26.5	5.4	12.5	20.5	67.4	79.2	40.3	40.8	46.1	50.7	88.4	2.42	69.7	17.18[4]	16.54	4.30	80.5
	1935	54.9	40.1	37.0	27.4	24.2	4.8	10.9	56.9	94.3	94.2	39.6	43.2	46.7	45.5	88.3	2.97	71.0	14.06	13.97	4.00	136.7
	1936	39.0	37.8	34.2	26.1	24.1	2.9	14.7	35.7	98.2	97.7	30.9	42.5	48.0	45.8	89.9	2.83	68.7	13.17	13.90	3.75	116.3
3-year average		42.7	39.0	35.9	27.6	24.9	4.4	12.4	37.7	86.6	90.4	36.9	42.2	46.9	47.3	88.9	2.74	69.8	14.80	14.80	4.01	111.2
Velvet	1934	31.6	40.4	36.6	27.6[3]	25.5	5.4	12.5	23.0	57.9	81.1	34.2	36.2	46.4	50.5	88.2	2.39	71.2	17.26[4]	17.14	5.33	110.5
	1935	45.9	40.0	36.2	24.4	20.7	4.9	11.7	59.4	93.0	93.2	35.7	37.2	46.7	46.6	86.3	3.28	72.0	14.42	14.44	5.14	164.0
	1936	37.4	39.7	34.7	24.7	22.2	3.5	13.2	37.2	94.5	93.0	29.1	38.0	47.4	45.6	89.5	2.84	70.9	14.75	14.25	4.67	149.8
3-year average		38.3	40.0	35.8	25.6	22.8	4.6	12.5	39.9	81.8	89.1	33.0	37.1	46.8	47.6	88.0	2.83	71.4	15.48	15.28	5.05	141.4
Manchuria	1934	29.4	40.1	36.2	26.2[3]	23.8	7.1	11.6	28.1	68.4	86.8	33.8	34.2	46.1	51.7	85.6	2.31	72.7	16.05[4]	16.57	5.42	127.8
	1935	37.5	39.2	34.7	24.2	21.1	4.4	10.5	68.9	97.0	93.7	31.7	30.7	46.4	46.6	84.5	3.29	73.3	15.16	14.89	5.96	189.3
	1936	30.2	39.2	33.2	24.2	20.8	6.1	12.0	38.2	93.7	97.2	25.7	34.2	48.6	47.0	88.7	2.81	72.1	14.49	14.18	5.34	198.7
3-year average		32.4	39.5	34.7	24.9	21.9	5.9	11.4	45.1	86.4	92.6	30.4	33.0	47.0	48.4	86.3	2.80	72.7	15.23	15.21	5.57	171.9
Trebi	1934	47.9	39.0	35.2	35.4[3]	33.3	5.0	13.3	14.7	45.8	73.1	45.3	46.0	46.2	50.2	89.5	2.16	72.4	14.78[4]	14.75	3.96	75.2
	1935	50.8	38.8	36.0	33.2	29.5	5.6	10.2	47.7	85.5	92.1	36.1	42.5	47.1	46.2	88.0	3.00	73.1	13.31	13.24	4.16	142.3
	1936	46.3	38.4	33.2	32.0	28.3	8.5	13.2	27.7	86.6	91.6	37.4	44.2	47.4	46.3	90.5	2.67	71.0	14.06	14.19	4.05	172.8
3-year average		48.3	38.7	34.8	33.5	30.4	6.4	12.2	30.1	72.6	85.6	39.6	44.2	46.9	47.6	89.3	2.61	72.2	14.05	14.06	4.06	130.1
Annual average 5 varieties	1934	32.9	39.8	36.2	29.3	27.1	6.0	12.5	22.2	58.6	81.2	37.5	38.5	46.2	50.9	87.8	2.36	71.6	16.64	16.52	4.96	108.9
	1935	45.1	39.3	35.9	27.0	23.5	4.5	11.0	60.1	93.0	93.5	35.4	37.4	46.8	46.4	86.4	3.15	72.7	14.32	14.34	4.96	164.4
	1936	36.9	38.9	33.9	26.4	23.5	5.1	13.3	35.1	94.1	95.5	30.9	38.7	47.7	46.4	89.2	2.80	70.8	14.24	14.26	4.57	167.7
Minimum significant difference between 3-year varietal average		3.7	0.8	1.0	0.9	1.4	—	0.7	4.8	5.7	—	—	—	—	—	1.3	0.08	1.2	0.66	0.56	0.28	13.7

[1] Five-stations average as data from Kanawha, Iowa, were not obtained in 1934.
[2] Index of mellowness was calculated as follows: Number of steely kernels × 0, number half-steely kernels × ½, number mellow kernels × 1, and sums added.
[3] Moisture content of barley was not determined at the same time kernel weight was obtained. Kernel weights of 1934 averages were calculated for comparative purposes on the basis of 12% moisture in the barleys.
[4] Four barleys only averaged in 1934 barley protein averages.

The average difference in protein content between the barleys and malts is consistent although not large in the three years. The differences in protein content between the barley and malt for all five varieties averaged together are as follows: 1934, 0.23%; 1935, 0.44%; and 1936, 0.18%. Sufficient data are not available to correlate these differences with any particular group of factors in the barleys and malts.

The average soluble nitrogen in the wort was lower for the malts from Oderbrucker, Wisconsin Barbless, Velvet and Manchuria in 1936 than in the previous two years. The percentage of soluble nitrogen in the wort is seemingly as closely correlated with total nitrogen in the barley and malt as with the diastatic power of the malt. This relationship is indicated by the fact that the soluble nitrogen is consistently lower in Wisconsin Barbless and Trebi than in the other three varieties. The relative order of the five varieties with respect to soluble nitrogen in the wort remained the same as in 1935. The data are presented in Tables XVIII and XXIII.

The modification in the malts as measured by protein degradation has varied from year to year and is different for the five varieties. The summary data showing nitrogen modification on the basis of total malt nitrogen, soluble nitrogen in the laboratory wort, and the per cent of the malt nitrogen which is soluble in the wort, are presented in Table XIX. These data are compared with kernel weight of the malts, recovery of malt from barley and diastatic power of the malts as suggested in the excellent review article by Laufer (1937). Data on permanently soluble nitrogen in the worts and formol nitrogen in the worts were not obtained for the malts from the 1934 and 1935 barleys; therefore the comparisons on the nitrogen modification on the three years' data were limited to soluble nitrogen in the worts. A more detailed comparison of modification was made on the malts from the 1936 barleys and this is given in Tables XX and XXI.

The nitrogen modification based on the per cent of the malt nitrogen which is soluble in the wort shows a significant negative correlation with the percentage recovery of malt from the barley. Seasonal and varietal differences are evident, however, in the summary data presented in Table XIX. The malts from the 1934 barleys were lowest in soluble nitrogen expressed as per cent of the total nitrogen in the malt. This probably is influenced somewhat by the method of drying the malts in 1934 and is also influenced by the abnormally high malt nitrogen. The malts from the 1935 barleys are significantly higher in per cent of malt nitrogen soluble in the wort and lower in

percentage recovery than either 1934 or 1936. The varieties likewise show differences in nitrogen modification based upon the ratio of soluble nitrogen in the wort to total malt nitrogen when averages are compared within an individual year as well as for the three-year average. Manchuria ranks highest in percentage of the malt nitrogen soluble in the wort, Oderbrucker, Velvet, Trebi, and Wisconsin Barbless following in descending order.

The more complete study of nitrogen modification made on the malts from the 1936 barleys suggests that Manchuria, Oderbrucker and Velvet are essentially alike based on the average of the eleven malts for each variety. The averages for the malts from the Wisconsin Barbless variety are appreciably lower than in the above three varieties but higher than Trebi. While the varietal averages for the malts show the general differences, a study of the individual malts from the barley varieties grown at the different locations shows many exceptions to the relative varietal ranking given in the summary table. (Tables XX and XXI.) The data given in more detailed form (Table XXI) show the range of variation found in the malts within a barley variety grown at the different locations or between varieties grown at one location. A number of interesting comparisons might be made from the data presented. The writers feel however that the one year's results are of value mainly in pointing out the impossibility of using any single factor in evaluating modification in a group of malts. This is illustrated by a comparison of the malts made from the low protein barleys from DeKalb, Illinois, with those from the relatively high nitrogen barleys grown at Waseca, Minnesota, and these in turn with the malts from the barleys grown at Bozeman, Montana. The data on the study of the nitrogen fractions are presented, therefore, as a progress report to make them available rather than to draw conclusions or attempt to discuss the differences. A study of chemical and physical methods for determining modification of malts is being continued.

The diastatic power of the malts from the five varieties showed considerable variation in 1936. The average diastatic power for the Oderbrucker, Manchuria and Trebi varieties was somewhat higher than in 1935. The diastatic power for the malts of Wisconsin Barbless and Velvet averaged lower than in 1935. Malts from the Wisconsin Barbless barleys grown in the north-central area were all lower in diastatic power than in the previous year. No general trend was evident in the diastatic power of the malts from the other varieties in this same area. The malts from the barleys grown at Bozeman, Montana, Fort Collins, Colorado, and Davis, California, were higher

in diastatic power than in the previous two years. The relative order of the varieties was the same as in 1935 except that Trebi and Velvet were reversed, the former being slightly higher in 1936. The data on diastatic power of the malts are given in Tables XXII and XXIII. The season in which the barleys were grown has a marked influence on diastatic power. This contrast has been exaggerated somewhat by the relatively low diastatic powers given for 1934. The malts produced from the 1934 barleys were dried for a longer period and to a lower moisture content which resulted in comparatively low diastatic values. The varieties have shown marked differences in diastatic power in each of the three years.

The time required in the mashing process to convert the starch to dextrins, "conversion time," has been used as a comparative measure of the dextrinizing capacity of the malts. The conversion time in the mashing process has not been determined in the exact intervals of minutes, but rather as outlined in the Official Methods of the American Society of Brewing Chemists. The comparison of conversion time for the various malts has been made by taking the average time in minutes recorded for each malt, as for example: less than 5 minutes was arbitrarily assigned the value of 4 minutes; 5 to 7 minutes, 6 minutes; 10 to 15 minutes, 12.5, etc. These numerical values in minutes were used in obtaining averages and in the statistical analysis.

The average rate of conversion of the starch to dextrins varied for the five varieties grown and malted in 1936. The average time of conversion for the five varieties grown at the eleven stations, listed in the earlier tables for 1936, was as follows: Oderbrucker 4.6, Manchuria 4.9, Velvet 5.7, Wisconsin Barbless 7.6, and Trebi 10.3 minutes, respectively. The time of conversion in the 1936 malts varied slightly from those in 1935. The malts from the different varieties varied decidedly in their ranking as to conversion time in the two years. The average time of conversion for the five varieties grown at twelve locations in 1935 was as follows: Manchuria 4.1, Velvet 4.4, Oderbrucker 4.6, Wisconsin Barbless 6.6, and Trebi 9.0, respectively. The time of conversion in the malts from the five varieties grown at eight stations in 1934 was slower than in the two years following. This may have been due in part to the difference in procedure in drying the malts in 1934. The malts were dried longer and at a higher temperature in the later phases of the drying which resulted in a lower moisture content and a lower diastatic power in the malts produced in 1934. The ranking of the malts for conversion time also varied from the two previous years. The average time of conversion for the malts from

the five varieties in 1934 was as follows: Oderbrucker 5.1, Velvet 5.9, Manchuria 6.4, Wisconsin Barbless 7.9, and Trebi 12.6 minutes, respectively. The three-year average for the five varieties—Oderbrucker 4.8, Manchuria 5.1, Velvet 5.3, Wisconsin Barbless 7.4, and Trebi 10.6 minutes, respectively—suggests relatively little difference in the conversion time in the first three varieties as the minimum significant difference between varietal averages is 1.8 minutes. These three varieties have shifted in their relative ranking for conversion time in each of the three years. The malts from Wisconsin Barbless and Trebi did not change position in any year and were significantly slower in time of conversion, Trebi malts taking twice the time required for the malts from the first three varieties. The average conversion time in minutes for the malts from the five varieties grown at the six stations was 7.6, 5.9, and 6.2, in 1934, 1935, and 1936, respectively.

The conversion time of the malts from the five varieties shows a significant negative correlation with diastatic power. The correlation is significant for each of the three years and for the combined three years' data. The correlation is higher in the malts produced in 1934 under the drying conditions which resulted in a lower diastatic power than in the last two years. The correlation values for each of the three years are as follows: 1934, $\gamma = -0.620$, 1935, $\gamma = -0.381$, and 1936, $\gamma = -0.387$. For the three years' data combined, $\gamma = -.510$. The 5% and 1% levels of significance are -0.197 and -0.260 respectively for the combined three years' data. In other words, the negative correlation between conversion time and diastatic power based on the three years' data is highly significant.

The analysis of variance applied to the three years' data on conversion time shows differences in reaction and interaction from that of diastatic power (Table XXV). Varieties appear to be the most important determining factor in conversion time with years second; location where grown seems of little importance. Interactions between varieties, stations and years are low and do not suggest differential responses in time of conversion.

These comparisons for the three years are only relative because the time of conversion was not recorded at close enough intervals to show the finer differences between Oderbrucker, Manchuria and Velvet. The results suggest, however, the importance of applying more precise methods of distinguishing between the different diastatic enzymes in the study of malts from the different barley varieties. The 1934 values also substantiate the idea that the dextrinizing enzyme or alpha-amylase is more heat stable than the saccharifying enzyme or beta-amylase.

Summary of Three Years' Data

As stated earlier in the paper, three years' data covering widely different conditions and a very limited number of varieties are not sufficient to warrant conclusive statements. The results are encouraging, however, in that they show consistent differences in response between the varieties used in the investigations, between the different stations where the five varieties are grown and between the three seasons. In other words, from the standpoint of methods, the investigational procedure and factors used to measure differences in quality appear to be applicable to the problem and fairly reliable. The results are further encouraging in that the varieties performed in a rather constant manner at the different stations and in the different years. Such information, if reliably founded on the limited scope of the present data, is encouraging for it suggests a relative stability of the varieties and the importance of germplasm in so far as quality has been measured by the factors used.

The average of the three years' data as given in each table for all stations for each of the five varieties is somewhat misleading as they tend to level out the varietal and seasonal differences in the various factors measured. The average of the data for the three years for each of the five varieties grown at the six comparable stations gives a more reliable comparison of the seasonal effect on quality (Table XXIII).

Averages for the stations within the given barley areas would perhaps more nearly reflect the condition of the general run of the commercial barley for each year. This phase of the problem of barley quality is not a part of the present paper and is mentioned merely to guard against the drawing of conclusions and applying them to the commercial crop of barley.

The average diastatic power of the malts produced in 1934 was very low and conversion time somewhat longer in contrast to those of 1935 and 1936. This is due in large part to the methods used in malting the 1934 barleys. The malts were dried to a final moisture content of about 3.6% in 1934. Later studies on the influence of drying showed that the low moistures reached in the malts in 1934 reduced the diastatic power below the values which would be obtained with a final moisture content of 4 to 5%. Therefore, the low figures for diastatic power in 1934 and somewhat slower rate of conversion are caused probably by prolonged drying rather than by seasonal conditions. In general the diastatic power should have been high in 1934 as there is a

relatively high positive correlation between protein and diastatic power.

Two characteristics of the 1936 barleys and malts are shown in the average data presented in Table XXIII, namely, the relatively low protein content of the 1936 barleys and the correspondingly low soluble nitrogen in the wort. This is somewhat contrary to expectations as a hot, dry season and hastened maturity are said to increase the protein content of barley. There is need of experimental work on the physiology of the barley plant as illustrated here and in numerous other instances.

A brief statistical analysis of yield and the more important quality factors was made. An analysis of variance was used for the data from the six stations where all five varieties were grown during the three-year period and the results are presented in Tables XXIV and XXV. Since only three years and a limited number of varieties were used, this analysis is presented as a preliminary indication of the relationships which may exist for the factors studied. The analysis was made on yield and on each of the quality factors as affected by varieties, stations, and years; the first order interactions, varieties × stations, varieties × years, and stations × years; and the second order interaction, varieties × stations × years. The following factors were studied: yield of grain, bushel weight of barley, bushel weight of malt, kernel weight of barley, kernel weight of malt, weight of hulls of barley, estimated time steeped to reach 46% moisture, mellowness of endosperm of dry barley, mellowness of endosperm after 24 to 30 hours' steep and drying, recovery of malt from barley, ash in barley, extract in malt, protein in barley, protein in malt, soluble nitrogen in wort as protein, diastatic power of malt and conversion time in mashing. The "F values" were calculated for each of these factors. These values represent the ratio of the second order interaction variance (varieties × stations × years) to the variance due to varieties, stations, years, etc. At the end of each table are given the 5% and 1% "F values" appropriate to each comparison. The design of the experiment was such that the second order interaction variance was the most appropriate to use as error. A significant "F value" for varieties indicates that some real differences exist among the varieties. The same is true for stations and years. Significant "F values" for first order interactions indicate that differential response is greater than that which might be attributed to chance alone.

The values of minimum significant differences for each factor were also obtained. These are appropriate to use in comparing the differ-

TABLE XXIV

ANALYSIS OF VARIANCE OF YIELD, BUSHEL WEIGHT OF BARLEY AND MALT, KERNEL WEIGHT OF BARLEY AND MALT, WEIGHT OF HULL OF BARLEY, TIME STEEPED TO REACH 46% MOISTURE, MELLOWNESS OF ENDOSPERM BEFORE AND AFTER STEEPING, AND RECOVERY OF MALT FROM BARLEY FOR FIVE VARIETIES OF BARLEY,[1] SIX STATIONS,[1] AND THREE YEARS [1, 2]

Variation due to	Degrees of freedom	Yield of barley bu. per A.		Bushel weight of barley, dry basis		Bushel weight of malt,[3] 4% basis		Kernel weight of barley, dry basis		Kernel weight of malt, dry basis		Weight of hull of barley, dry basis		Estimated time to reach 46% moisture		Mellowness of endosperm, dry barley		Mellowness of endosperm after steeping 24–30 hrs.[3]		Recovery of malt from barley, dry basis		5% point F. value	1% point F. value
		Variance	F. value	Variance	F. value	Variance	F. value	Variance	F. value	Variance	F. value	Variance	F. value	Variance	F. value	Variance	F. value	Variance	F. value	Variance	F. value		
Varieties	4	1,018.36	33.71	4.55	2.94	4.89	2.49	226.42	133.19	202.50	45.56	4.63	4.51	239.99	6.43	608.79	11.74	481.09	7.79	32.80	9.11	2.61	3.83
Stations	5	5,517.08	182.62	147.85	95.39	143.64	73.29	217.15	127.73	208.12	46.83	33.39	32.50	878.16	23.54	736.78	14.21	194.92	3.16	20.39	5.66	2.45	3.51
Years	2	1.149.17	38.04	6.04	3.90	38.30	19.54	102.97	60.57	131.05	29.49	41.59	40.48	341.10	9.14	11,135.07	214.80	10,215.62	165.43	62.22	17.28	3.23	5.18
Varieties × stations	20	109.22	3.62	1.91	1.23	2.16	1.10	1.59	0.93	3.48	0.78	1.55	1.50	44.56	1.19	58.04	1.12	37.27	0.60	3.18	0.88	1.85	2.40
Varieties × years	8	89.40	2.96	2.27	1.46	1.48	0.76	1.31	0.77	3.40	0.77	2.42	2.35	41.77	1.12	46.89	0.90	90.81	1.47	3.05	0.85	2.18	2.99
Stations × years	10	653.43	21.63	52.65	33.97	32.84	16.76	57.80	34.00	43.12	9.70	11.30	11.00	304.18	8.15	571.33	11.02	179.63	2.83	27.69	7.69	2.09	2.82
Varieties × stations × years	40	30.21		1.55		1.96		1.70		4.44		1.03		37.30		51.84		61.75		3.60			
Total	89																						

[1] Stations used are: East Lansing, Mich., Madison, Wis., Waseca, Minn., Kanawha, Iowa (data from Emmetsburg, Iowa, were used in 1935 instead of Kanawha as samples were not malted from the latter station), Brookings, S. D., and Bozeman, Montana. Varieties used are: Oderbrucker, Wisconsin Barbless, Velvet, Manchuria, and Trebi. Years represent barleys grown in 1934, 1935, and 1936.

[2] Manchuria (Minn. 184) at Waseca, Minnesota, was substituted in 1936 for Manchuria (N. Dak. 2121).

[3] Five stations only were used in analysis of variance of bushel weight of malt and mellowness of endosperm after steeping, the data from Kanawha, Iowa, not being available. Degrees of freedom are reduced accordingly for these two factors and F. values for the 5% and 1% points are changed as follows: 5% point—2.67, 2.67, 3.30, 1.99, 2.25, and 2.25; 1% point—3.97, 3.97, 5.34, 2.68, 3.13, and 3.13.

TABLE XXV

ANALYSIS OF VARIANCE OF ASH IN BARLEY, EXTRACT IN MALT, PROTEIN IN BARLEY AND MALT, SOLUBLE NITROGEN AS PROTEIN IN WORT FROM MALT, AND DIASTATIC POWER OF MALT FOR FIVE VARIETIES OF BARLEY,[1] SIX STATIONS,[1] AND THREE YEARS[1, 2]

Variation due to	Degrees of freedom	Ash in barley		Extract in malt, dry basis		Protein in barley [3]		Protein in malt		Soluble N. in wort as protein		Diastatic power of malt		Conversion time in mashing		5% point	1% point
		Variance	F. value	Variance	F. value	Variance	F. value	Variance	F. value	Variance	F. value	Variance	F. value	Variance	F. value	F. value	F. value
Varieties	4	.172	11.90	24.24	7.91	8.78	9.03	7.84	10.90	10.14	57.74	14,938.93	35.44	74.34	9.72	2.61	3.83
Stations	5	.458	31.59	40.97	13.38	5.78	5.95	11.35	15.77	4.97	28.28	2,393.18	5.66	5.93	0.77	2.45	3.51
Years	2	4.660	321.38	32.34	10.56	52.53	54.07	49.20	68.36	1.55	8.82	32,722.21	77.39	24.30	3.18	3.23	5.18
Varieties × stations	20	1.800	124.14	1.17	0.38	0.80	0.82	0.66	0.91	0.20	1.16	456.90	1.08	6.84	0.89	1.85	2.40
Varieties × years	8	.050	3.45	0.62	0.20	2.26	2.33	1.61	2.24	0.31	1.78	1,194.71	2.82	4.43	0.58	2.18	2.99
Stations × years	10	.186	12.83	24.15	7.89	10.05	10.35	13.13	18.24	1.95	11.10	2,286.58	5.41	15.22	1.99	2.09	2.82
Varieties × stations × years	40	.014		3.06		0.97		0.72		0.18		422.83		7.65			
Total	89																

[1] Stations used are: East Lansing, Mich., Madison, Wis., Waseca, Minn., Kanawha, Iowa (data from Emmetsburg, Iowa, were used in 1935 instead of Kanawha as samples were not malted from the latter station), Brookings, S. Dak., and Bozeman, Mont. Varieties used are: Oderbrucker, Wisconsin Barbless, Velvet, Manchuria, and Trebi. Years represent barleys grown in 1934, 1935, and 1936.

[2] Manchuria (Minn. 184), at Waseca, Minnesota, was substituted in 1936 for Manchuria (N. Dak. 2121) as grain from the latter was not furnished from this station in 1936.

[3] Protein in malt was substituted for protein in barley in 1934 for samples from East Lansing, Mich., and Waseca, Minn.

ences between varietal means for the three-year period (Table XXIII).

By using the second order interaction (varieties × stations × years) as error the following conclusions suggest themselves.

For each of the factors studied some varieties were found to be superior to others except in the case of bushel weight of malt. This does not mean that a specific variety is superior for all of the factors, but rather that for each factor there can be shown to be a variety or varieties which are superior to others. For example it was found that for the three-year period the malt recovery of Wisconsin Barbless was significantly greater than for Oderbrucker, while for extract yield, diastatic power and conversion time the same two varieties also showed a significant difference but in the reverse order.

For each of the factors studied, except conversion, some stations were shown to differ significantly from others, *e.g.*, the kernel weight of barley at Bozeman, Montana, was found to be greater than at Brookings, South Dakota.

For each of the quality factors studied it was found that the yearly crops differed very significantly from each other.

The stations × years interaction was found to be significantly greater than error for each of the factors studied except conversion. The large interaction in every case was due in part to the radically different seasonal conditions which prevailed during the three years of the study.

The varieties × stations interaction was found to be insignificant for all of the factors studied except yield of grain, and ash in barley. In those cases where low interactions were obtained it shows that in general the varieties held the same relative rank at the different stations. They permit the extension of the results obtained in the form of regional recommendations. This may be illustrated in the case of extract of malt. In Table XV the average extract of malt of Wisconsin Barbless for the six stations during the three years is found to be 69.8%. This is the lowest value for the five varieties listed. Now since the varieties × stations interaction is not significant it is to be expected that Wisconsin Barbless will be relatively low in extract at the several stations. A detailed inspection of Table XV bears out this generalization.

The low interaction of varieties × stations suggests that the varieties produced by the barley breeder have a general regional application for all factors except yield of grain and ash in the barley. For these factors specific attention will have to be given to more localized areas.

To the barley buyer it means that he can buy a single variety over a wide geographical area and have considerable assurance that its quality will hold a relative position to that of another variety grown in the same area. This does not mean there will be no fluctuations in the quality of the variety bought. It does mean that the quality will be about the same relative to other varieties, *e.g.*, Oderbrucker will almost always give a higher diastatic power than Wisconsin Barbless no matter in what part of the area the two varieties are grown.

The varieties × years interaction was found to be insignificant for some of the factors studied and for those the varieties behaved similarly in the different years. Where the interaction attained a significant level the varieties did not react similarly in the different years. The factors where this is the case are as follows: yield of grain, per cent of hull, ash in barley, protein in barley, protein in malt, and diastatic power. The interaction for the diastatic power was probably somewhat inflated by the fact that after the first year the malting procedure was changed in an important step affecting this factor.

It appears that the relative ranking of varieties for some of the factors is more easily upset by the season than by the location. For other factors neither of these seems to play a part. And lastly there are factors in which both year and location seem to operate.

Summary

Data on the variability of malting controls for the three years are presented and discussed. Although there was considerable variability in the malting process the results are sufficiently accurate to calculate differences between varieties, stations and seasons.

The discussion of the experimental malting of the barleys grown in 1936 and the three years' data for the five varieties grown at the co-operating agricultural experiment stations are presented.

The 1936 barleys were of poorer quality than those of 1935 especially from the stations in the upper Mississippi Valley section.

The five varieties studied retained approximately the same relative positions in 1936 as in 1935, with the exception of Wisconsin Barbless, which was most adversely affected by the hot dry season which hastened maturity.

Three years' data on the five varieties are summarized and discussed. A brief statistical analysis of yield and the more important quality factors is given.

The data indicate that the varieties performed in a rather constant manner at the different stations and in the different years.

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IMPROVING THE NUTRITIVE VALUE OF BREAD BY THE ADDITION OF DRY MILK SOLIDS[1]

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It has been fifteen years since Sherman and Hawley (1922) published their widely quoted paper giving the first experimental and scientific evidence to support the recommendation of one quart of milk a day for every child. Today a study of the milk consumption figures reveals that on the average the children of the United States are consuming much less than a quart of milk per child per day. In order to appreciate fully the situation as it really exists it must be noted that this low consumption of milk is a fact in spite of the wholehearted support given to milk consumption by the medical and dental professions, the dietitians, health organizations, government agencies, parent-teachers associations and the financial assistance provided by the dairy interests largely through their various organizations. This is neither the time nor place to speculate upon causes or attempt to formulate reasons. The fact is the point of interest.

If the recommendation of Sherman and Hawley is still nutritionally sound, the problem confronting the nutritionist today is that of increasing the consumption of milk solids by children. Any innovation must not in any way detract from the efforts made to increase the consumption of liquid milk for this has the general endorsement of all interested in child nutrition. We seek a way by which liquid milk consumption will be augmented, and it is suggested that this may be accomplished by the judicious addition of milk solids to some of the regular and staple articles found in the American diet.

There is no other article of food that is so generally and universally consumed as bread. The baking technologist has demonstrated that the addition of milk solids to the bread formula is both feasible and practicable. In fact, there is quite a list of advantages attributed to the adding of milk solids to bread. If it can be demonstrated that the addition of milk solids will increase the nutritive value of the bread, the nutritionist would be justified in accepting milk-solids bread as a means of augmenting our present inadequate liquid milk consumption. It may be argued that the above reasoning implies that bread without

[1] This investigation was made possible by the donation of funds to the University of Illinois by the American Dry Milk Institute, Inc.

the addition of milk solids is without nutritive value. No such implication is intended nor would it be justified as any student of foods would attest. There should be no objection in attempting to improve a product especially when such an improvement is a means to attain a desired objective

It is the purpose of this present work to compare the over-all nutritive value of bread made without milk solids, with bread made with the addition of 6% milk solids (based upon the weight of flour) and with bread made with the addition of 12% milk solids. The experimental technique employed in this initial work is not capable of explaining in terms of nutrition why observed differences occur. At present we are only interested in the differences, and further experiments which are better controlled and more refined in procedures will be conducted to explain that which has been observed and recorded here. While the general results of this comparison are quite predictable, it seems advisable to report the findings as the nutrition literature of today does not seem to include any observations upon this particular point.

Review of Literature

The place of wheat in the American diet and the value of milk as a supplement to wheat have been discussed in a general way by Taylor (1929). "Nutritionally considered, the place of wheat in the diet may be anywhere up to, let us say, two-thirds of the calories of the diet. The higher the proportion of wheat, or other cereal, in the diet, the greater the care necessary to secure the indispensable elements in order to avoid deficiency diseases. . . . A broad survey of modern knowledge of nutrition, in a country with the agricultural characteristics of the United States, indicates that nutritional security in the diet is to be sought in the milk supply and that wheat (and other cereals) ought to serve as fuel food."

The nutrition literature records a few attempts to feed white bread as the sole diet or as a major portion of the diet to experimental subjects. The results are not in perfect agreement probably due to variations in bread formulae or lack of uniformity in experimental procedures. Hartwell (1924) fed a diet of white bread, butter, and a salt mixture to young growing rats and reports a slow rate of growth. In gestation and lactation tests, the litters were of poor weight at birth and only a few of the young were raised to the weaning age. In two trials, Abelin (1919, 1931) fed white bread to rats. There were a marked retardation of growth, changes in the bone, infections of the skin and mucous membranes, falling of the hair, eye injuries, and general weakness. In one experiment the animals died usually after three or four months. Cosla and Vasilco (1932) fed a dog exclusively

on white bread and nutritive troubles identical with those observed in general avitaminosis and avitaminosis *B* as well as experimental scurvy were noted. Eyerly, Oclassen, and Killian (1935) fed diets composed largely of bread to rats and demonstrated no deficiencies in growth-promoting factors but excessive gains in weight were not obtained. Throughout several generations of feeding, a large amount of bread did not produce any inhibition of calcification in the young nor any decalcification in mature animals.

There is evidence that the proteins of wheat may be deficient in their nutritive value. Mitchell and Smuts (1932) have demonstrated by the paired-feeding method that wheat is deficient in the indispensable amino acid lysine, and that when lysine is added there is a large increase in the growth-promoting value of the wheat. French and Mattill (1935) conclude that the proteins of bread may be grouped in the same class as meat proteins and are inferior only to the proteins of milk and eggs. This conclusion hardly seems justified as the white bread contained milk and the supplementary effect of milk and wheat proteins is ignored.

There does seem to be agreement among investigators that the vitamin B content (B-complex) of bread is low. Its importance in practical nutrition is another matter. Eijkmann and Hulshoff Pol (1918) produced polyneuritis in fowls fed white bread. Gault (1923) noted variations in the nutritive values of patent flour breads made with different amounts of yeast cakes. Veselkin, Yaroslavtzeva, Seliber, and Bovshilk (1927) concluded that white bread containing 0.5% of baker's yeast produced about one-half the vitamin necessary to maintain weight in the pigeon. Morgan and Frederick (1935) found practically no loss of the vitamin during baking at temperatures ranging from 300° to 446° F. The addition of 4% dry milk solids did not change the vitamin B_1 content of white bread, and bread sold as "milk bread" was equal to ordinary white bread in vitamin B_1 content.

As this paper is concerned primarily with the supplementary effect of milk solids when added to a white bread formula, the following reports may be considered as having a direct bearing upon the investigation. McCollum, Simmonds, and Parsons (1921) found milk to be an effective supplement to wheat, with respect to protein, calcium, and vitamin A. Fairbanks and Mitchell (1935) report a biological value of 89.8 for the proteins of raw liquid skim milk, 88.8 for a choice commercial roller process skim milk powder, and 87.9 for a preheated spray process powder. Rose, MacLeod, and Bisbey (1923) working with human subjects report a protein storage in 12 days of 30.37 grams on bread and milk as compared to 41.44 grams on milk, 4.33 grams on

meat and 2.12 grams on soybeans. Bernfeld and Schilf (1930) fed young rats bread and water or bread and liquid milk. On diets of bread and water the rats died after about six weeks. If milk was given one to two weeks before death was expected, the animals suddenly recovered and began to gain in weight.

Materials and Methods

The three types of bread were made in the baking laboratory of the Division of Agricultural Biochemistry, Department of Agriculture, University of Minnesota, by Olof Stamberg, Fellow, American Dry Milk Institute.

Three doughs were made by the straight dough method. The flour used was a blend of spring wheat flours and typical of the ordinary commercial blends used for bread baking. The formula employed was exactly the same except for the variation in the percentage of dry milk solid with a resulting variation in absorption. The formula used was as follows, in percentages based on the amount of flour used:

3% Sugar
1% Diastatic malt extract
2% Shortening
2% Salt
3% Yeast
0, 6, or 12% Dry milk solids

The fermentation time used was two hours with about 35 minutes of pan proof. The dough was baked in one-pound bread pans at 200 to 230° C. for approximately 45 minutes and stored overnight in a proofing cabinet.

The top, bottom and side crusts were shaved off and eliminated, and the resulting bread crumb was cut into thin slices and placed for about 12 to 14 hours in a drying cabinet maintained at 40 to 50° C. The dry crumb was then ground in a meat chopper.

The dry bread crumb was shipped via express to the Division of Animal Nutrition, University of Illinois. When received it was stored under refrigeration until fed.

The experimental subjects were Albino rats weighing approximately 50 grams at the beginning of the experiment. Twenty-one rats were used and they were divided into three groups. The attempt was made to equate the three groups in respect to initial weight, sex, and breeding as determined by litter. The distribution is presented in Table 1. Each rat was confined to an individual cage.

Group 1 was fed a sole diet of water bread (0% milk solids) and water; Group 2 received 6% milk-solids bread, and water, and Group 3

received 12% milk-solids bread, and water. The feed was weighed out to the rats daily. Scattering was reduced by adding water to the bread crumb, but this was not entirely avoided, especially when large quantities of bread were fed. The amount of scattering was not enough to vitiate the results in this type of experiment. Daily weights of the rats were recorded. The experimental feeding period was 77 days.

The *ad libitum* method of feeding was employed. It is appreciated that this method of feeding has certain objectionable features in a nutrition experiment. When food intake is not controlled and equated, it is difficult to assess differences to nutritive value or to the variations in food consumed. But in this initial experiment the gross or overall nutritive value was the point of interest and this would include palatability.

TABLE I

WATER BREAD VS. 6% MILK-SOLIDS BREAD VS. 12% MILK-SOLIDS BREAD
(*Ad Libitum* Feeding)

INITIAL WEIGHT, SEX, AND LITTER OF 21 RATS DISTRIBUTED IN THREE GROUPS

Water bread				6% Milk-solids bread				12% Milk-solids bread			
Rat number	Initial weight	Sex	Litter	Rat number	Initial weight	Sex	Litter	Rat number	Initial weight	Sex	Litter
22	63	Male	L1R1	23	52	Female	L1R1	24	51	Male	L1R1
25	45	Female	L2	26	53	Male	L2	27	56	Male	L1
28	49	Female	R2	29	51	Female	R2	30	51	Male	R2
31	42	Male	R1	32	60	Male	R1	33	46	Female	R1
34	49	Female	L2R1	35	46	Female	NM	36	45	Female	NM
37	45	Female	L2R1	38	50	Male	NM	39	59	Female	L1
40	56	Male	L2	41	47	Female	R1	42	48	Male	NM

Experimental Results

The weekly food consumption and weekly gains of the individual rats are recorded by groups in Table II. The average weekly gains of the rats receiving 6% milk-solids bread were higher for every week than those receiving the water bread. The weekly gains of the 12% milk-solids bread group exceeded the average weekly gains of those receiving 6% milk-solids bread except in two instances, the ninth and tenth weeks.

Using food consumption as an index to palatability a very interesting and regular set of data is presented in Table II. The average food consumption of the rats is always the lowest in the water bread group; the 6% milk-solids group takes the middle position, while the highest average weekly food consumption is always the highest in the group receiving 12% milk-solids bread. The only exception to this statement is in the first week, when the rats receiving 6% milk-solids

TABLE II

Weekly Food Consumption and Weekly Gains of Individual Rats Recorded by Groups

Rat No.	1st Week		2nd Week		3rd Week		4th Week		5th Week		6th Week		7th Week		8th Week		9th Week		10th Week		11th Week	
	Gain	Food	Gain	Food	Gain	Food	Gain	Food	Gain	Food	Gain	Food	Gain	Food	Gain	Food	Gain	Food	Gain	Food	Gain	Food
Water bread																						
22	0	42	8	76	4	119	10	105	−10	25	7	56	7	51	6	91	−5	65	−4	48	0	49
25	3	36	6	46	1	47	2	24	−3	27	−2	25	−1	29	6	36	−3	28	−2	29	9	39
28	7	40	6	62	0	51	3	46	3	35	−6	30	8	31	−8	23	0	36	2	46	−9	15
31	0	24	9	40	0	32	3	24	1	34	3	32	15	45	−2	28	−1	32	4	42	7	49
34	3	42	9	79	3	92	1	60	−3	28				Died								
37	18	42	12	76	−2	44	6	45	6	43	3	47	6	42	4	40	0	47	−14	15	13	60
40	4	42	6	55	2	77	14	81	−1	31	7	50	14	57	3	49	12	53	−3	45	18	70
Av.	5.0	38.3	7.0	62.0	1.1	66.0	5.6	55.0	−1.0	31.9	2.0	40.0	8.2	42.5	1.5	44.5	0.5	43.5	−2.8	37.5	6.3	47.0
6% Milk-solids bread																						
23	11	42	26	91	17	98	9	75	6	61	8	77	11	66	14	79	0	74	12	89	2	88
26	10	42	24	82	14	74	4	57	6	49	12	56	25	84	12	91	14	98	3	84	9	91
29	8	42	14	55	13	89	30	96	9	64	20	83	7	66	21	91	−2	74	14	96	11	91
32	10	42	19	91	12	77	4	42	15	64	13	68	12	66	24	97	21	113	8	114	4	70
35	3	42	14	64	3	56	12	54	−1	31	4	47	−6	21	17	55	22	71	−5	51	10	58
38	12	42	15	91	7	95	−9	30	15	61	−24	11	12	35	6	48	20	64	12	65	22	78
41	11	42	11	46	6	44	9	42	−21	10	−9	15	14	45	16	49	6	56	19	63	14	67
Av.	9.3	42.0	17.6	74.3	10.3	76.1	8.4	56.6	4.1	48.6	3.4	51.0	10.7	54.7	15.6	72.9	11.6	78.6	9.0	80.3	10.3	77.6
12% Milk-solids bread																						
24	13	42	31	88	44	119	15	102	11	73	28	107	22	105	−1	79	17	98	7	90	27	109
27	13	42	25	73	31	95	−12	42	−5	21	23	70	37	98	13	78	5	73	−12	53	20	84
30	17	42	29	88	18	72	42	102	30	103	8	85	7	65	27	105	4	88	23	110	5	87
33	14	42	22	70	24	86	−1	48	14	61	10	59	1	51	18	70	−1	53	11	72	−1	52
36	10	42	24	75	22	82	16	74	−7	39	17	70	28	89	9	69	15	79	−10	52	19	81
39	11	42	32	88	30	95	4	72	16	82	−20	32	16	63	27	85	7	71	13	87	11	79
42	11	36	20	68	11	75	10	46	6	44	24	63	32	94	19	134	5	105	22	131	25	120
Av.	12.7	41.0	26.1	78.6	25.7	89.1	10.6	69.4	9.3	60.4	12.9	69.4	20.4	80.7	16.0	88.6	7.4	81.0	7.7	85.0	15.1	88.8

bread averaged 42 grams, while those receiving 12% milk-solids bread consumed on the average 41 grams. This difference of one gram, especially during the first week, can well be ignored.

Only one rat died during the experiment and this was Rat 31 in the water bread group. The daily notes of the experiments show that this rat did very poorly at the beginning of the test, improved during the second week, after which it went off feed. There were no pronounced symptoms of any disorders. The rat was thin and in poor condition, and did show a thinness of hair coat, but this latter condition was observed in several rats receiving only water bread.

Table III summarizes the results for the individual rats by groups,

TABLE III

SUMMARY BY INDIVIDUAL RATS AND GROUPS OF RATS SHOWING GAINS, FOOD CONSUMPTION AND ECONOMY OF GAIN

Rat No.	Initial weight	Final weight	Gain weight	Av. daily gain	Total food consumed	Av. daily food consumed	Feed fed per gram gain
Water bread							
22	63	86	23	0.30	727	9.4	31.6
25	45	61	16	0.21	366	4.8	22.9
28	49	55	6	0.08	415	5.4	69.2
31	42	81	39	0.51	382	5.0	9.8
34	49	Died					
37	45	97	52	0.68	501	6.5	9.6
40	56	132	76	0.99	610	7.9	8.0
Av.	49.9	85.3	35.3	0.46	500.2	6.5	25.2
6% Milk-solids bread							
23	52	168	116	1.51	840	10.9	7.2
26	53	186	133	1.73	808	10.5	6.1
29	51	196	145	1.88	847	11.0	5.8
32	60	202	142	1.84	844	11.0	5.9
35	46	119	73	0.95	550	7.1	7.5
38	50	138	88	1.14	620	8.1	7.0
41	47	121	74	0.96	479	6.2	6.5
Av.	51.3	161.4	110.1	1.43	712.6	9.3	6.6
12% Milk-solids bread							
24	51	265	214	2.78	1012	13.1	4.7
27	56	194	138	1.79	729	9.5	5.3
30	51	261	210	2.73	947	12.3	4.5
33	46	157	111	1.44	664	8.6	6.0
36	45	188	143	1.86	752	9.8	5.3
39	59	206	147	1.91	796	10.3	5.4
42	48	233	185	2.40	926	12.0	5.0
Av.	50.9	214.9	164.0	2.13	832.3	10.8	5.2

while Table IV is a summary of the results by groups. The rats receiving water bread gained 35.3 grams, those of the second group 110.1 grams, while the rats on 12% milk-solids bread gained on the average 164.0 grams. The gains by groups are presented graphically in Figure 1.

TABLE IV

SUMMARY OF RESULTS BY GROUPS

Group	Av. initial weight	Av. final weight	Av. gain	Av. daily gain	Av. total food consumed	Av. daily food consumed	Av. feed fed per gram of gain
Water bread	49.9	85.3	35.3	0.46	500.2	6.5	25.2
6% Milk-solids bread	51.3	161.4	110.1	1.43	712.6	9.3	6.6
12% Milk-solids bread	50.9	214.9	164.0	2.13	832.3	10.8	5.2

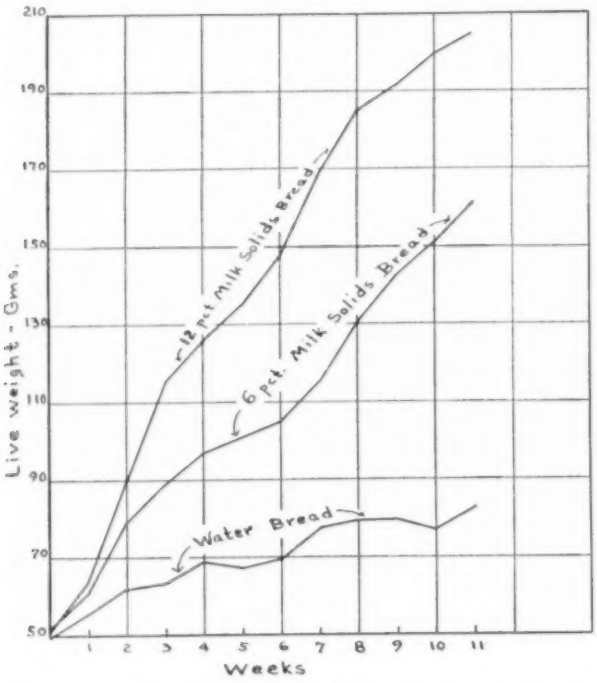

Figure 1. Growth curves of rats fed water bread, 6% milk-solids bread, and 12% milk-solids bread (*ad libitum* feeding).

The total food consumed by the rats in the water bread group was 500.2 grams per rat, for the second group 712.6 grams, and for the third group 832.3 grams. The weakness of *ad libitum* method of feeding is here revealed. All of the observed differences in gains can not be attributed to differences in nutritive values of the three types of

bread, as food consumption in the three groups is not the same. The influence of differences in palatability has not been ruled out. But it is a safe assumption, after food consumption figures are compared to gains, that not all of the additional gains of the second and third groups as compared to the water bread group are due alone to a greater food consumption. This assumption is substantiated in the figures under

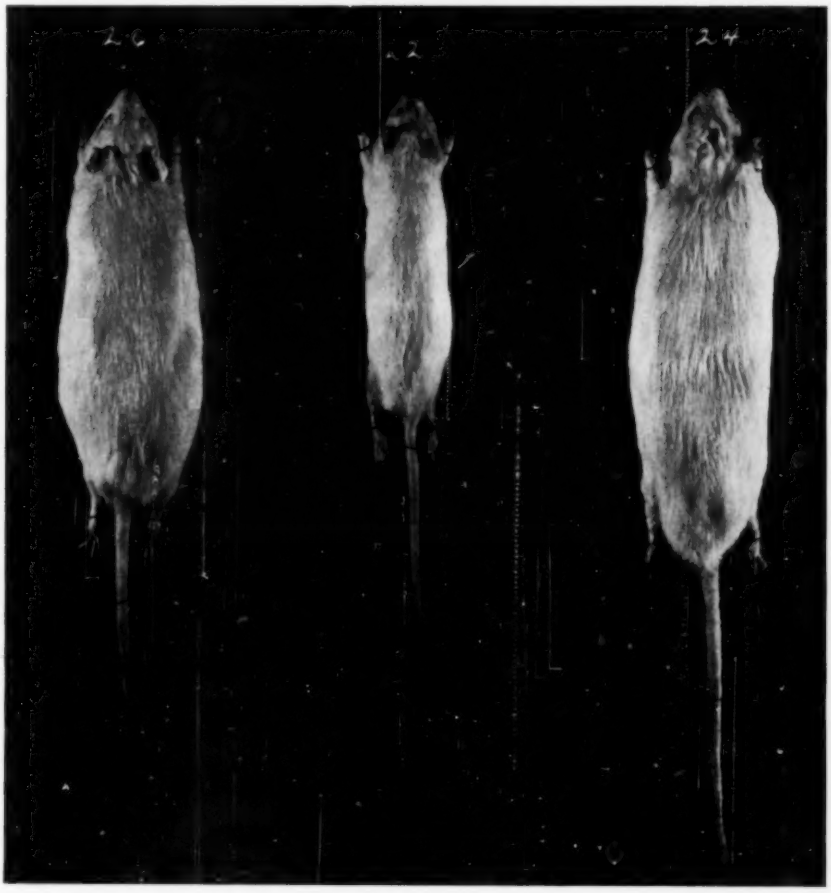

Figure 2. Skin mounting of representative rat from each group.

the average feed fed per gram of gain. It is admitted that these figures can not be taken as a true index of the comparative nutritive values of the three types of bread, as differences in maintenance requirements are not considered. But it can be said that 5.2 grams of 12% milk-solids bread satisfied the maintenance requirements of a much heavier rat than the other two groups and put on a gram of gain,

while in the case of the 6% milk-solids bread, 6.6 grams of bread maintained a smaller rat than the third group and a much larger rat than the first group and put on a gram of gain; and it required 25.2 grams of water bread to maintain a much smaller rat and put on an equal unit of gain. It therefore seems reasonable to assume that differences in nutritive values of the three types have been qualita-

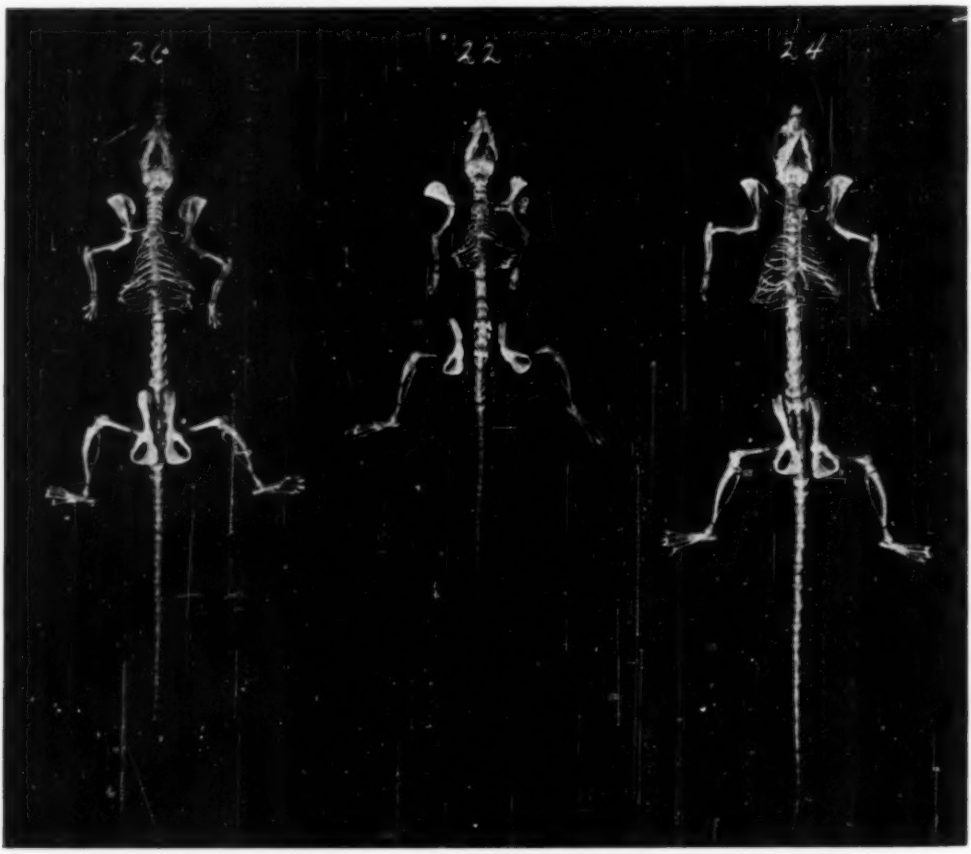

Figure 3. Skeleton mounting of rat from each group.

tively demonstrated but not quantitatively. From a practical point of view perhaps these fundamental points of interpretation of experimental data are not significant but they have been included for the sake of scientific accuracy and completeness.

L. A. Adams, Department of Zoology of the University of Illinois, made a skeleton and skin mounting of a representative rat from each of the three groups. (Figures 2 and 3). Rat 22 received water bread, Rat 26 received 6% milk-solids bread, and Rat 24 was fed the 12%

milk-solids bread. Dr. Adams reports that he experienced great difficulty in mounting the skeleton of Rat 22, as the bones were very fragile and had a tendency to crumble and break with handling.

Conclusions

By the *ad libitum* method of feeding it has been demonstrated that the addition of milk solids to a water bread (no milk) formula increases the nutritive value of the bread.

There is evidence that the nutritive value of bread containing 12% milk solids is of a higher order than bread containing 6% milk solids.

Most nutritionists are in agreement that the present consumption of liquid milk should be maintained and that efforts should be continued to increase it. Statistics indicate that the per capita consumption of liquid milk is below that recommended by authorities in nutrition. The results of this experiment indicate that the addition of milk solids to bread is an excellent method of augmenting milk consumption and thereby improving the dietary of the American people.

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THE EFFECT ON FLOUR STRENGTH OF INCREASING THE PROTEIN CONTENT BY ADDITION OF DRIED GLUTEN [1]

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Introduction

In a preceding paper, the authors (1934) showed that with a series of high grade Canadian hard red spring wheats, a linear relationship existed between protein content and loaf volume, from which they concluded that when wheats of the same class are under consideration protein content is a reliable index of strength.

Blish and Sandstedt (1935) point out that there is "a general unwillingness to accept protein content as a trustworthy index to strength when wheats of different classes or varieties are under consideration, because variations in gluten quantity are alleged to be overshadowed by inherent differences in 'quality,'" and while recognizing that glutens from different sources vary in their characteristics, they express the view that "protein content and inherent flour strength are one and the same thing."

It is well known that world wheats such as English, Australian, Argentine and Canadian differ widely both in protein content and gluten characteristics and, in view of this, it has not heretofore been possible to determine whether the very wide differences in their inherent strength are a reflection of variations in protein content, gluten character or both. Were it possible accurately to increase the protein content of "weak" to that of "strong" wheat flours, by the addition of the corresponding glutens, the influence of protein "character," or as it is generally termed "gluten quality," on flour strength could be evaluated. The use of wet gluten for such a purpose offers experimental difficulties from the standpoint of accurately determining the amount necessary to add and the possibility of changes in physical characteristics during the time required for moisture and protein determinations. To overcome these difficulties, a method has been developed whereby dried gluten of flour-like fineness may be prepared which will reform wet gluten closely resembling its original physical properties. With such preparations from different flours, the in-

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vestigation here reported has been conducted with a view to determining the relative importance of variations in protein content and protein "character" in relation to the baking strength of typical world wheats.

Experimental

Preparation and Properties of Dried Gluten

As high temperatures denature gluten, rendering it incapable of reforming wet gluten and valueless for increasing baking strength, it is necessary to conduct the drying at comparatively low temperatures and with sufficient rapidity to preclude putrefaction. In order to accomplish this and to permit drying wet glutens prepared from different flours under identical conditions, the experimental drying cabinet for alimentary pastes described by Binnington and Geddes (1934) was utilized. The glutens were washed from flour-water doughs by kneading under frequent changes of tepid water until most of the starch was removed; no attempt was made to obtain a relatively starch-free product, as the presence of small quantities of starch appeared to facilitate drying. The wet gluten was divided into small pellets weighing about four grams, placed on waxed paper trays and dried in the macaroni cabinet at 32° C. in a circulating air flow of approximately 400 cubic feet per minute, from which the moisture was condensed on cooling coils. The gluten was dried to a horny-like mass in 24 hours and was reduced to flour-like particles in the Allis-Chalmers experimental mill. The final product was bolted through a 9-XX silk and contained approximately 8% moisture and 60 to 70% protein, the yield varying from 10 to 20%, depending upon the type of flour.

In selecting the drying conditions adopted, the object was to employ as low a drying temperature as possible without putrefaction, and no attempt was made to ascertain whether higher temperatures could be safely used. Alsberg and Griffing (1927) showed that heating wet gluten at temperatures from 30 to 50° C. resulted in no impairment of swelling power; in fact, the evidence indicated a slight increase, and heat coagulation at the temperature of 32° C. employed in this study would not be expected to occur. The similarity in appearance and feel of corresponding wet and wetted-dried glutens was very striking but the latter were, if anything, slightly more elastic, more extensible and firmer.

In this preliminary study, extensive tests were not undertaken to secure a quantitative measure of differences in physical properties between the wet and wetted-dried glutens from corresponding flours; however, the extent of dispersion of the dried glutens in 0.05N acetic acid was found to be in the order of 6% lower than the corresponding

freshly prepared glutens, this variation being practically constant for the different samples tested. It would therefore appear that the drying had slightly altered the gluten, but as the extent of the changes appeared to be uniform, the material was considered satisfactory for the purpose of this study.

Experimental Material and Methods

Twelve world wheats of widely varying baking strength, representing the strong, filler and weak classes, were experimentally milled into long patent flours, portions of which were used for preparing dried glutens as described. The flours and dried glutens were tested for moisture and protein content, and the necessary quantity of corresponding dried gluten added to each flour to raise the protein level to that of the highest in the series (Canadian Average No. 1 Northern), the flour-gluten blends being thoroughly mixed in a MacLellan mixer. In this manner, two series of samples were provided, the one varying in both protein content and gluten character, and the other only in the latter. In addition, the protein contents of two of the weakest flours in the series, namely, German and Italian, were raised to that of Canadian by the addition of No. 1 Northern gluten, thus permitting a direct comparison between the strength of so-called "weak" flours plus "weak" gluten and "weak" flours plus "strong" gluten of the same protein level. The flours investigated, together with protein data, are listed in Table I.

For the purpose of determining the comparative baking strengths of the original and gluten-treated flours, the samples were baked by the malt-phosphate-bromate method in which 0.3 g. diastatic malt (approximately 250° Lintner), 0.1 g. $NH_4H_2PO_4$, and 0.001 g. $KBrO_3$ are superimposed upon the ingredients specified in the A. A. C. C. Basic Baking Test outlined by Geddes (1934).

While it is admitted that flours possessing such widely varying strength characteristics as those included in this investigation undoubtedly possess different optimum fermentation and proving times, little definite information is available to indicate what these times should be. Experience (Aitken and Geddes, 1934; Kent-Jones and Geddes, 1936) has shown that of numerous formulas the malt-phosphate-bromate procedure widely differentiates between flours of varying and of similar strength characteristics and, accordingly, this baking procedure was used in the present study.

To determine the effect of additions of dried gluten on the type of curve produced by the Brabender Farinograph, farinograms were made on flour-water doughs at a consistency of 600 Brabender units employing 50 g. of flour (13.5% moisture basis).

TABLE I

FLOURS STUDIED AND PROTEIN DATA [1]

Reference number	Sample	Flour protein	Protein in dried gluten	Dried gluten added	Final flour protein
		%	%	%	%
	Original and corresponding gluten-treated flours				
1	Canadian Average No. 1 Northern	13.7	63.4	nil	13.7
2	Canadian Average No. 2 C.W. Garnet	11.2	66.1	4.25	13.8
3	Canadian Average No. 5 (frosted)	12.9	68.4	1.34	13.7
4	Russian	12.5	67.6	2.03	13.9
5	German	8.4	70.6	7.92	13.6
6	Hungarian	11.7	66.8	3.37	13.8
7	English, ordinary	8.0	68.9	8.70	13.7
8	English, Yeoman	8.0	69.4	8.66	13.7
9	Argentine	10.5	65.6	5.43	13.9
10	Argentine	12.1	66.4	2.76	13.9
11	Australian	9.2	69.7	6.99	13.6
12	Italian	10.5	65.9	5.38	13.7
	Original and Canadian gluten-treated flours				
13	German (No. 5)	8.4	63.4	10.40	13.9
14	Italian (No. 12)	10.5	63.4	6.90	13.8

[1] All values are expressed on a 13.5% moisture basis.

Baking Results

From the mean baking data recorded in Table II, it will be noted that the addition of dried gluten markedly increased absorption, improved dough handling characteristics, increased loaf volume and enhanced loaf appearance and crumb texture but imparted a greyish yellow colour to the crumb.

Regarding absorption, that of the original flours varied from 51.6 to 61.6% as compared with 55.6 to 63.6% for the gluten-treated flours, individual increases being as great as 5% in the instance of the lowest protein flours. While the range in absorption is only narrowed by 2% by equalizing the protein content, the majority of the gluten-treated flours have absorptions ranging from 58.6 to 60.6%, the outstanding exceptions being ordinary English, German and Italian.

In dough-handling characteristics, the improvement due to the added gluten was very striking, particularly with the English, Italian and German, which normally yield short, sticky, tender and inelastic doughs; the corresponding treated flour doughs exhibited medium strength dough characteristics, similar to those of a good Argentine.

TABLE II

Mean Flour Protein and Comparative Baking Data

Reference number	Sample	Flour protein I	Absorption[1]	Mean loaf volume	Crumb score: Texture	Crumb score: Colour	Crust colour	Form	Dough characteristics at time of panning
		%	%	c.c.					
1	Canadian Average No. 1 Northern	13.7	60.6	925	6	7 y.	S.	4.5	Excellent elasticity and spring; very gassy; exceedingly "strong."
2	Canadian Average No. 2 C. W. Garnet	11.2	55.6	618	5.5 C. and o.	4.5 gy.	S.	2 sl.s.	Only fair elasticity and spring; somewhat short. Medium strength.
2 G.[2]	Canadian Average No. 2. C. W. Garnet plus gluten	13.8	59.6	738	5.5 C. and o.	3.5 gy.	S.	4	Good elasticity and spring; not short. Markedly superior to No. 2. Very good strength.
3	Canadian Average No. 5	12.9	60.6	735	5.5 C. and o.	6.5 y.	S.	3 s.	Good spring and elasticity; somewhat tender. Good to medium strength.
3 G.	Canadian Average No. 5 plus gluten	13.7	62.6	765	5.5 C. and o.	5 gy.	S.	4	Very good strength; closely resembles Average No. 1 Northern in all respects.
4	Russian	12.5	57.6	728	6.5	7 y.	S.	3 s.	Good elasticity and spring; somewhat tough. Good medium strength.
4 G.	Russian plus gluten	13.9	59.6	775	7	6.5 gy.	S.	4	Equal to Average No. 1 Northern in all respects.
5	German	8.4	51.6	525	5 Cl.	7.5	VP.	1.5 s.	Very short and clay-like.
5 G.	German plus gluten	13.6	55.6	640	7	7 g.	S.	4	Shortness absent; marked improvement in spring and elasticity. Medium strength.
5 CG.[3]	German plus Average No. 1 Northern gluten	13.9	57.6	715	7	6.5 g.	S.	4.5	Very similar to Average No. 1 Northern in all respects.
6	Hungarian	11.7	58.6	695	7	7.5	S.	3 s.	Very fair elasticity and spring; somewhat tender. Medium strength.
6 G.	Hungarian plus gluten	13.8	60.6	795	6.5	7 y.	S.	4	Very similar to Average No. 1 Northern in all respects.
7	English, ordinary	8.0	53.6	455	3 C.	4.5 g.	P.	1 f.	Lifeless; very short and clay-like. Very poor strength.
7 G.	English plus gluten	13.7	57.6	595	5 Cl.	3 g.	S.	3 s.	Fair elasticity and spring; very great improvement in strength when compared with No. 7.
8	English Yeoman	8.0	55.6	522	4 C.	7.5	P.	1 f.	Clay-like, rather short and tender. Poor strength.
8 G.	English Yeoman plus gluten	13.7	60.6	725	5.5 C. and o.	6.5 gy.	S.	3 s.	Shortness absent; very fair elasticity and spring; resembles good Argentine.
9	Argentine	10.5	55.6	692	7	7 g.	S.	4	Fair spring and elasticity; somewhat tender. Medium strength.
9 G.	Argentine plus gluten	13.9	59.6	815	7	6.5 gy.	S.	4	Very similar to Average No. 1 Northern in all respects.
10	Argentine	12.1	56.6	675	6.5	6.5 gy.	S.	4.5	Similar to No. 9.
10 G.	Argentine plus gluten	13.9	58.6	725	6.5	6.5 g.	S.	4.5	Very similar to Average No. 1 Northern in most respects; somewhat less springy.
11	Australian	9.2	53.6	535	5 Cl.	5 y.	P.	2	Short, clay-like and tender. Fair strength only.
11 G.	Australian plus gluten	13.6	58.6	732	7	5 y.	S.	4.5	Closely resembles Average No. 1 Northern but somewhat tender.
12	Italian	10.5	61.6	550	4 C.	1.5 y.	S.	2	Slack, tender, somewhat sticky.
12 G.	Italian plus gluten	13.7	63.6	655	4.5 C.	1.5 y.	D.	2	Fairly springy; practically no stickiness, rather like medium quality Argentine.
12 CG.	Italian plus Average No. 1 Northern gluten	13.8	63.6	768	7	3 y.	D.	4	Very similar to good Argentine.

[1] 13.5% moisture basis.
[2] G. = Gluten.
[3] C. = Canadian.

Table abbreviations
Crumb texture: (Perfect score 10). C. = Coarse; Cl. = Close; o. = open.
Crumb colour: (Perfect score 10). g. = grey; y. = yellow.
Crust colour: S. = Satisfactory; P. = Pale; D. = Dark; V. = Very.
Form: (Perfect score 5). s. = shell-top; f. = flat; sl. = slightly.

English Yeoman, Australian and Argentine were "transformed" to medium strength "Manitoba" doughs, such as Atlantic No. 3 Northern.

In loaf volume, the addition of dried gluten, as shown in Figures 1 and 2, imparted marked improvement, particularly to the flours of low protein content. The loaf volumes for the untreated flours ranged from 455 c.c. to 925 c.c., a spread of 470 c.c., as compared with

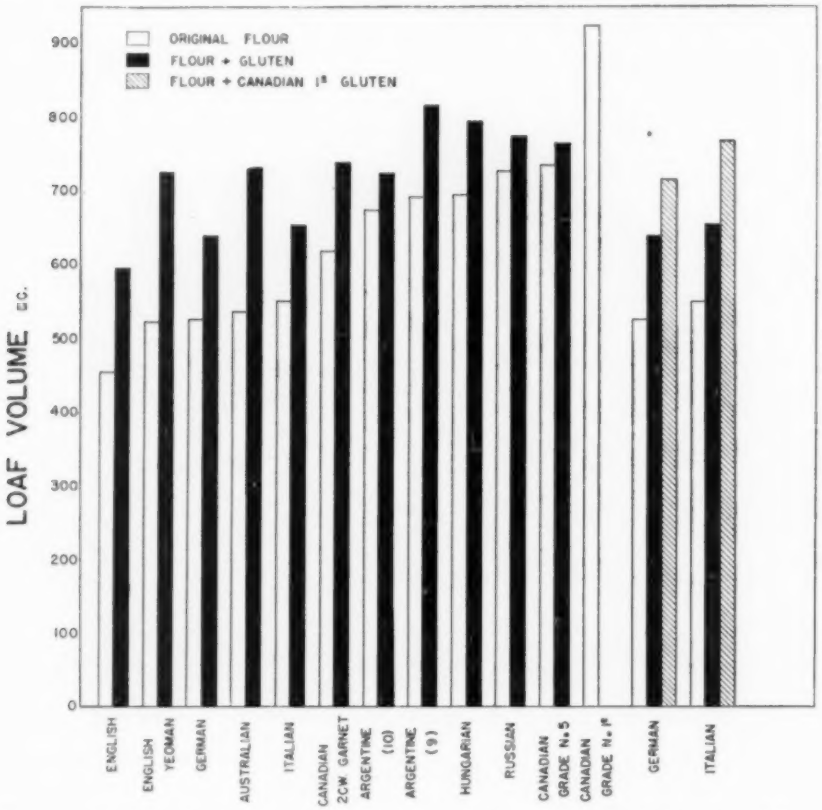


Figure 1. Histogram showing the comparative loaf volumes for the original and gluten-treated flours.

595 to 925 c.c., or a spread of 330 c.c., for the gluten-treated flours; that is, by equalizing the protein content the spread has been reduced by 140 c.c. or approximately 30%. However, this hardly gives a fair representation of the general improvement in strength, since, omitting the three weakest samples, namely, ordinary English, German and Italian and the very strong Canadian No. 1 Northern, the loaf volumes for the remaining eight gluten-treated flours all fell within a range of 90 c.c. as compared with 213 c.c. for the original flours. Within this

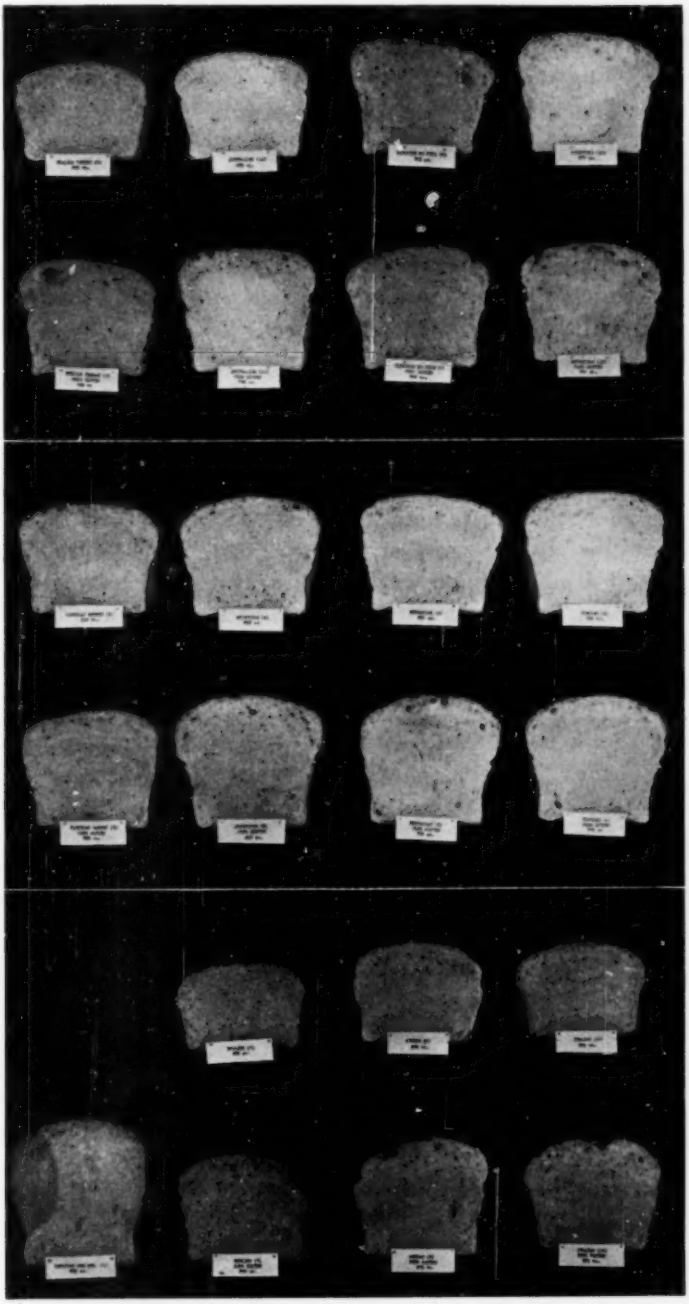


Figure 2. Photographs showing the cut surfaces of loaves baked from the various flours with and without additions of the corresponding dried glutens.

group, five of the treated flours, namely, English Yeoman, Australian, Garnet, Argentine and Russian gave loaf volumes of between 725 c.c. and 775 c.c., as compared with 522 to 728 c.c or a spread of 200 c.c. for the original flours. From this it would appear that, with the exception of the types of wheat which are considered to be representative of extremes as regards baking potentiality, namely, weak European and strong Canadian, protein content is the most important factor affecting baking strength; in other words, wheats such as average quality English Yeoman, Australian, Garnet, Argentine, Hungarian, Russian and Canadian No. 5 frosted would appear to possess protein having similar strength-imparting characteristics.

However, since any changes induced in the glutens as a result of drying appeared to be uniform for all samples, there is fairly definite evidence that baking strength is in part influenced by so-called "gluten quality." While none of the treated flours yielded loaves equal in volume to the strong Canadian, the fact that the latter sample contained no added gluten renders this less conclusive than the relative results obtained by adding "strong" versus "weak" gluten to the German and Italian flours. The addition of their own glutens increased the loaf volume of the German and Italian flours by 115 c.c. and 105 c.c. respectively, whereas the Canadian gluten caused increases of 190 c.c. and 218 c.c., as illustrated in Figures 1 and 3.

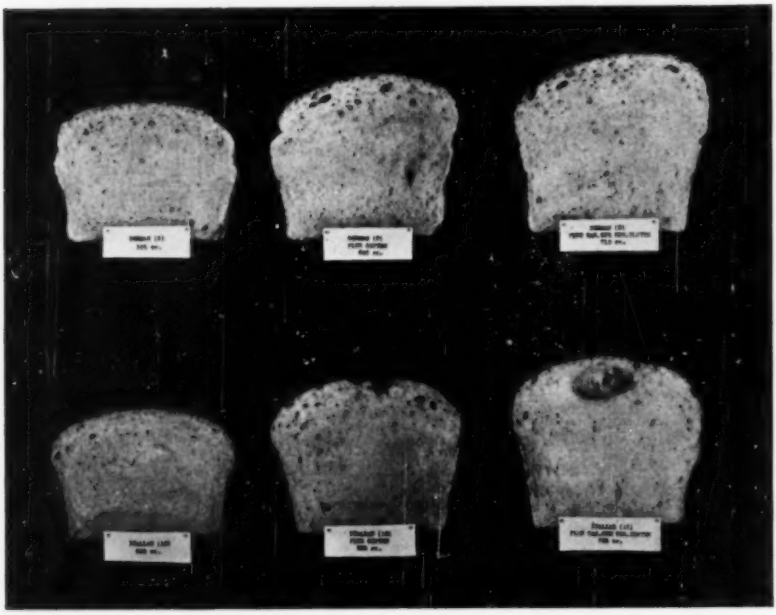


Figure 3. Photograph showing the cut surfaces of loaves baked from German and Italian flours, together with those for these flours with additions of their own versus "Canadian" dried gluten.

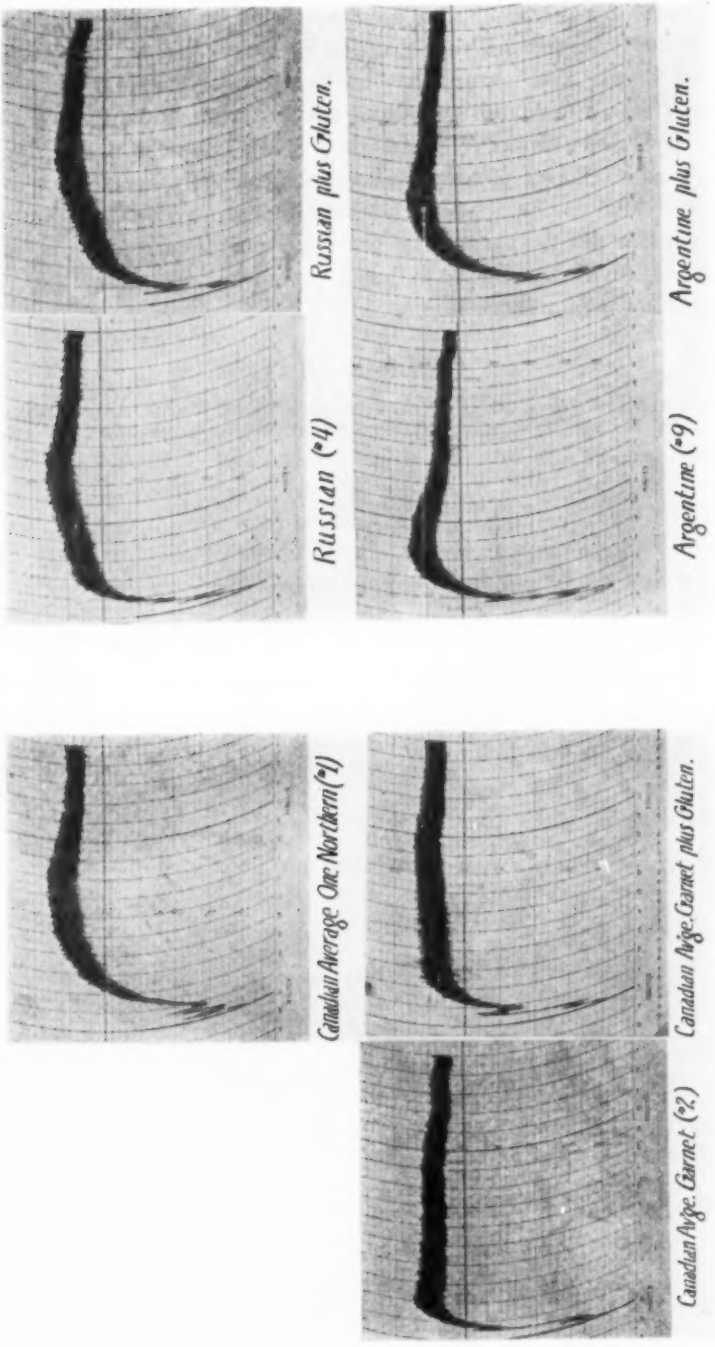
With reference to other loaf characteristics, the external appearance was markedly improved, the loaves being more "bold" and possessing superior break and shred, by the gluten additions. In internal characteristics the crumb grain and texture were not impaired and in many cases were improved, but the crumb colour was inferior, the gluten-treated flours yielding loaves possessing a decided yellow or greyish-yellow colour. This undesirable feature could undoubtedly be minimized by preparing the glutens from bleached flours, as the carotenoid pigments are to a large extent adsorbed by the gluten during the washing process.

TABLE III

COMPARATIVE DOUGH DEVELOPMENT TIME AND WATER ABSORPTION OF FLOURS WITH AND WITHOUT ADDITIONS OF DRIED GLUTEN

Reference number	Sample	Absorption [3]	Dough development time
		%	*Minutes*
1	Canadian Average No. 1 Northern	58.4	7.5
2	Canadian Average No. 2 C. W. Garnet	54.6	2.0
2 G.[1]	Canadian Average No. 2 C. W. Garnet plus gluten	56.4	8.0
3	Canadian Average No. 5 (frosted)	59.0	3.5
3 G.	Canadian Average No. 5 (frosted) plus gluten	60.4	5.5
4	Russian	55.6	7.5
4 G.	Russian plus gluten	57.6	7.5
5	German	49.8	1.0
5 G.	German plus gluten	53.8	2.5
5 CG.[2]	German plus Average No. 1 Northern gluten	55.8	5.5
6	Hungarian	56.6	3.0
6 G.	Hungarian plus gluten	59.0	3.0
7	English, ordinary	51.2	0.5
7 G.	English plus gluten	55.2	2.5
8	English Yeoman	52.4	1.5
8 G.	English Yeoman plus gluten	57.4	3.5
9	Argentine	54.0	3.5
9 G.	Argentine plus gluten	58.0	5.0
10	Argentine	54.8	2.5
10 G.	Argentine plus gluten	56.4	2.5
11	Australian	52.0	1.5
11 G.	Australian plus gluten	56.4	3.5
12	Italian	63.2	2.0
12 G.	Italian plus gluten	65.4	3.0
12 CG.	Italian plus Average No. 1 Northern gluten	63.2	4.0

[1] G. = corresponding gluten.
[2] CG. = Canadian No. 1 Northern gluten.
[3] 13.5% moisture basis.


Russian (4)
Russian plus Gluten.
Argentine (9)
Argentine plus Gluten.
Canadian Average Oat Northern (1)
Canadian Avge. Garnet (2)
Canadian Avge. Garnet plus Gluten.

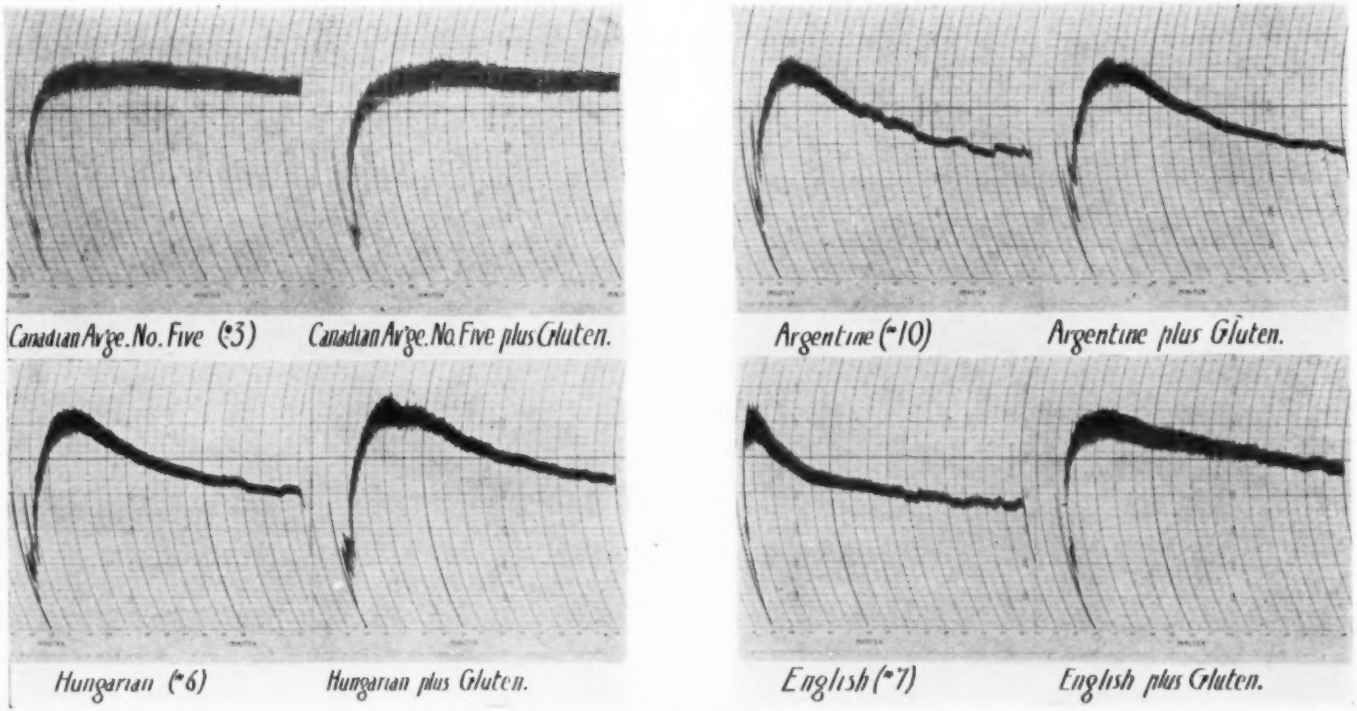


Figure 4. Farinograms for the original and gluten-treated flours.

Figure 4 continued on page 192.

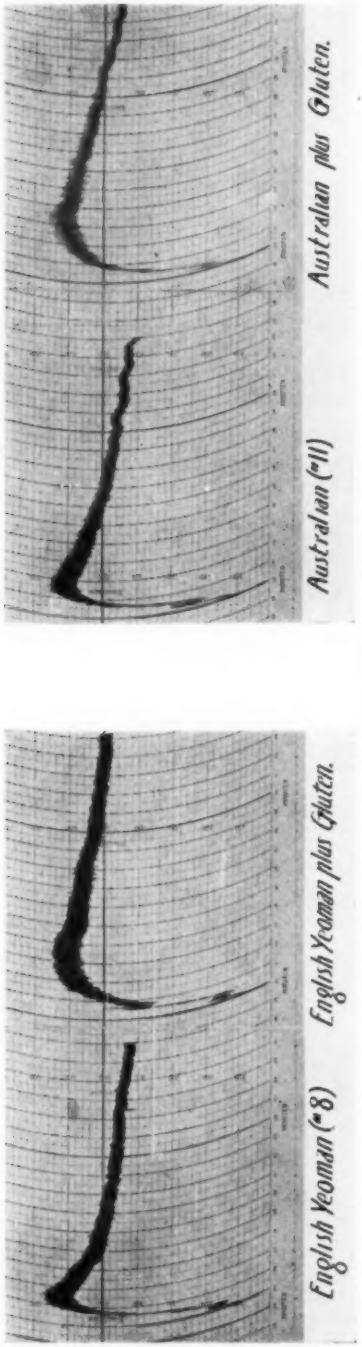


Figure 4 (continued). Farinograms for the original and gluten-treated flours.

Farinograph Results

The farinograms obtained are reproduced in Figures 4 and 5, and the absorptions required to bring the doughs to a Brabender consistency of 600 units, together with the "dough development time" in minutes as read from the curves, are given in Table III.

The water absorption and "dough development time" were, in general, increased by the gluten additions.

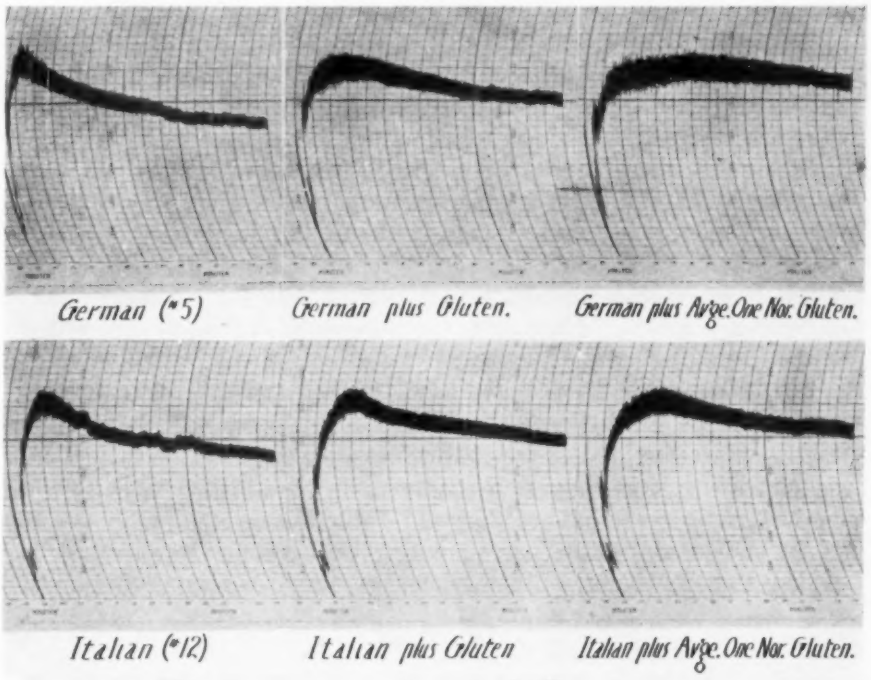


Figure 5. Farinograms for German and Italian flours, and those for these flours with additions of their own versus "Canadian" dried gluten.

Considering the general type and shape of the corresponding curves, it is evident that in the majority of cases improvement resulted from raising the protein level by the added gluten. This is particularly noticeable in the case of the English, English Yeoman, Australian and Italian flours which, as evidenced by curve appearance, were transformed from weak flours to those of the Argentine type. The improvement in the German and Italian flours due to the addition of Canadian gluten is most striking, the final curves resembling respectively those from a medium strength Canadian and a good Argentine. Neither the Russian, Hungarian nor Argentine curves were noticeably altered by the gluten additions.

The farinograms for the gluten-treated flours, in general, showed less improvement in flour strength than that evidenced by the loaf volume data and in several instances flours of the same protein and loaf volume levels gave quite different types of curves. Considering the curves for the gluten-treated flours as a whole, it is quite obvious that the dough characteristics as measured by the farinograph are not merely a reflection of protein content.

Effect of Storage on the Keeping Quality of Dried Gluten

In order to determine whether deterioration takes place in the strength-imparting properties of dried gluten after storage, additional baking tests were made with several of the glutens which had been stored in capped bottles for approximately ten months.

For this purpose, four of the original wheats, *i.e.*, Italian, German, Garnet and Argentine, were experimentally milled to the same extraction as formerly, care being taken in the milling to provide a second lot of flours which would be essentially the same as those formerly milled; protein tests showed a variation of only 0.1% between corresponding samples. Portions of the original dried glutens were added to the freshly milled corresponding flours to raise the protein content to the level originally selected, *i.e.*, 13.7%, thus permitting comparisons to be made between their baking strength and that of the original gluten-treated flours. The loaf volume results obtained by the malt-phosphate-bromate procedure and those by the same baking method originally found are shown in Table IV.

As indicated by the corresponding loaf volume increases, it is evident that dried gluten did not deteriorate after ten months' storage.

Discussion

This preliminary study reveals that dried gluten can readily be prepared which will reform wet gluten closely resembling freshly washed gluten in general handling properties and, when added to a weak flour, will impart strong flour characteristics, as indicated by increased water absorption, improved dough handling quality, loaf volume, loaf appearance and type of farinogram. There are definite indications that certain types of flours such as those milled from English Yeoman, Australian, Argentine, Russian, Hungarian, Canadian frosted and Garnet wheats differ in baking strength chiefly on account of variations in protein content, and that with such types "protein character" is of lesser importance.

On the other hand, with flours milled from the weakest types of wheats such as English, German and Italian, and from very strong types, such as high grade Canadian, definite differences in "protein

TABLE IV

LOAF VOLUME DATA OF FLOURS PLUS GLUTENS BEFORE AND AFTER APPROXIMATELY TEN MONTHS' STORAGE OF THE GLUTENS

Reference number	Sample	Original loaf volume		Loaf volume 10 months' later	
			Increase due to gluten addition		Increase due to gluten addition
		C.c.	%	*C.c.*	%
2	Canadian Average No. 2 C. W. Garnet	618	—	662	—
2 G.	Canadian Average No. 2 C. W. Garnet plus gluten	738	19.5	772	16.6
10	Argentine	675	—	705	—
10 G.	Argentine plus gluten	725	7.4	758	7.5
12	Italian	550	—	542	—
12 G.	Italian plus gluten	655	19.1	632	16.6
5	German	525	—	572	—
5 G.	German plus gluten	640	21.9	712	24.5

character" were evidenced. In other words, the weakest wheats are "weak" not only because of low protein content but also because of the inferior character of the protein or gluten. Similarly, the superior strength of Canadian No. 1 Northern is attributable to both high protein content and superior strength-imparting properties of its gluten. While increasing the protein content of weak flours by the addition of their own dried gluten resulted in marked general improvement, the addition of "strong gluten" produced more pronounced beneficial effects. Weak flours like English, German and Italian, which normally yield doughs of poor handling quality, take on "Manitoba" characteristics as shown by improvement in elasticity, spring and stability.

The question naturally arises as to whether any difference exists in the strength-imparting properties of wet and dried gluten from the same source and if subsequent tests indicate that the glutens are essentially the same in this regard, or that the dried glutens from various sources are modified to the same extent, a technique is provided for measuring differences in the gluten character of different grades of flour, varieties, grades and classes of wheat.

Summary

By employing a low drying temperature of 32° C. and a rapid air flow, dry gluten has been prepared which, after reducing to flour-like

fineness, yields wet gluten closely resembling freshly prepared wet gluten from corresponding flours in the major physical properties as indicated by hand manipulation. Limited tests indicated that the degree of dispersion in 0.05N acetic acid has been somewhat lowered as a result of drying.

Dried glutens prepared from experimentally milled flours representing weak, intermediate and strong world wheats, when added to the corresponding flours to equalize their protein contents, resulted in decided improvement in flour strength as indicated by absorption, dough-handling quality, loaf volume and loaf appearance. The crumb texture of the gluten-treated loaves was either unimpaired or improved but the crumb colour was deleteriously affected, being decidedly more yellow or greyish-yellow.

There are indications that wheats like English Yeoman, Australian, Hungarian, Argentine, Russian, Canadian frosted and Garnet possess glutens of similar character, and that their varying strength characteristics are due primarily to differences in protein content; with wheats of this type, protein content is a satisfactory index of strength. Wheats such as ordinary English, German and Italian are essentially "weak" because of deficient protein content coupled with gluten of unsatisfactory, weak character; on the other hand, high grade, high protein Canadian wheat owes its superior baking potentiality to its high protein level combined with gluten of good "quality."

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X-RAY PHOTOGRAPHS AS A MEANS OF DETERMINING WHEN A DOUGH IS ADEQUATELY MIXED

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(Received for publication July 29, 1937)

The standard experimental baking test as outlined in "Cereal Laboratory Methods" and "Methods of Analyses of the Association of Official Agricultural Chemists" specifies the use of the Hobart-Swanson mixer and a one-minute mixing period. The choice of a one-minute mix for the standard basic procedure is a necessary precaution because prolonging the mixing period beyond one minute will, in many cases, over-develop the gluten and thus adversely affect the baking properties of the dough. This is particularly true of doughs made from weak flours.

However, there has been some doubt concerning the mixing thoroughness when only a one-minute mixing period is used. The following investigation was undertaken to determine if a one-minute mix is sufficient to obtain a uniform distribution of the dough ingredients.

Method

The procedure adopted was as follows: One hundred grams of flour on a 15% moisture basis were placed in the bowl of the Hobart-Swanson mixer and a suspension of barium sulphate added plus sufficient water to produce a dough of the proper consistency. The quantity of barium sulphate added was $6\frac{1}{2}\%$ because this figure corresponds with the total amount of ingredients added in the form of yeast, sugar and salt in the standard baking test. Doughs were made up in this manner from cracker, baker's patent, and strong, clear-grade flours, and mixing periods varying from one to four minutes were investigated.

The procedure adopted for determining mixing thoroughness was to X-ray the doughs containing the barium sulphate. This was accomplished by rounding up the dough, as it comes from the mixer, in the same manner as though it were to be placed in the graniteware fermentation bowl. The rounded dough was placed on the sup-

porting plate of the X-ray machine and pressed to a uniform thickness by the use of a greased glass plate. The pictures are made by passing the X-rays directly down through the entire dough.

Figures 1, 2 and 3 are typical X-ray pictures of three doughs made from the same flour, the mixing period being the only variable. If after mixing the doughs were entirely homogeneous, the intensity of

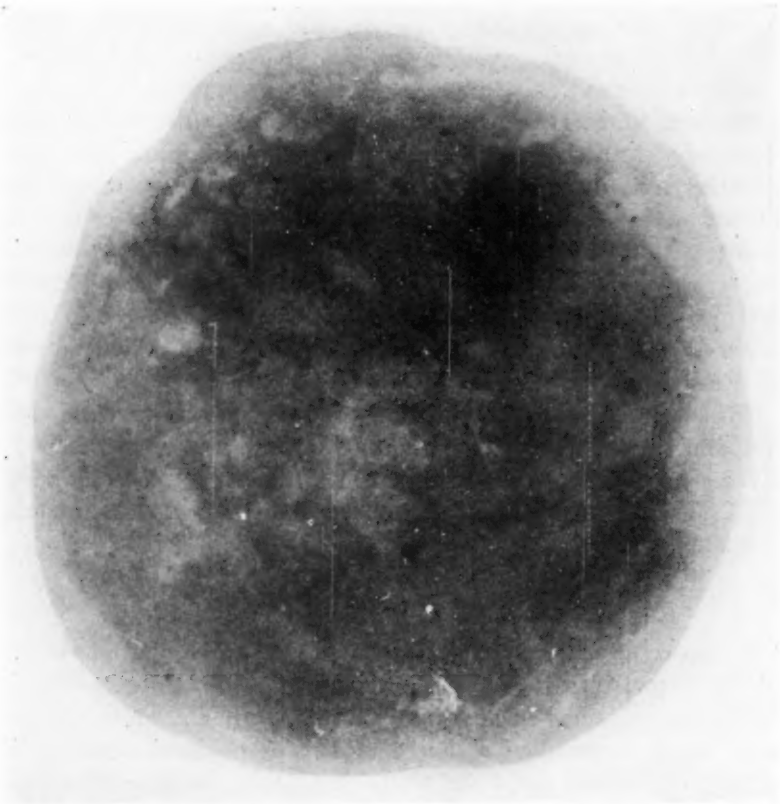

Figure 1. X-ray picture of a dough containing 6½% barium sulphate after a one-minute mix.

the shadow effect produced by the presence of the barium sulphate would be of equal intensity throughout the central portion since the X-rays are actually penetrating the same thickness of material. The appearance of the outer portion of the dough should be disregarded. In the present case a small quantity of larger pieces of barium sulphate was added in order that the mixing could be more easily followed.

When only powdered barium sulphate is used the shadow effect showing the lack of uniform distribution of the barium sulphate is sometimes difficult to see and requires a trained technician to properly interpret the picture.

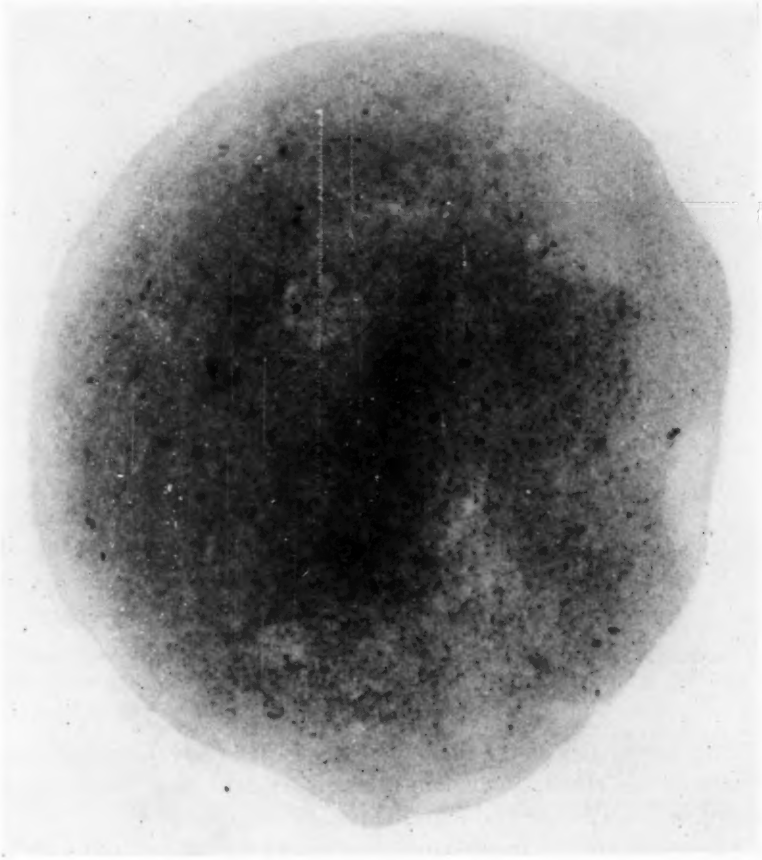

Figure 2. X-ray picture of the same dough in Figure 1 after being mixed two minutes.

These pictures indicate clearly that a one-minute mixing period is not adequate for thorough incorporation of the ingredients. Notice the grouping of the barium sulphate particles and the light shaded areas (Figure 1). Figures 2 and 3 show that the additional mixing has produced a uniform distribution of the barium sulphate.

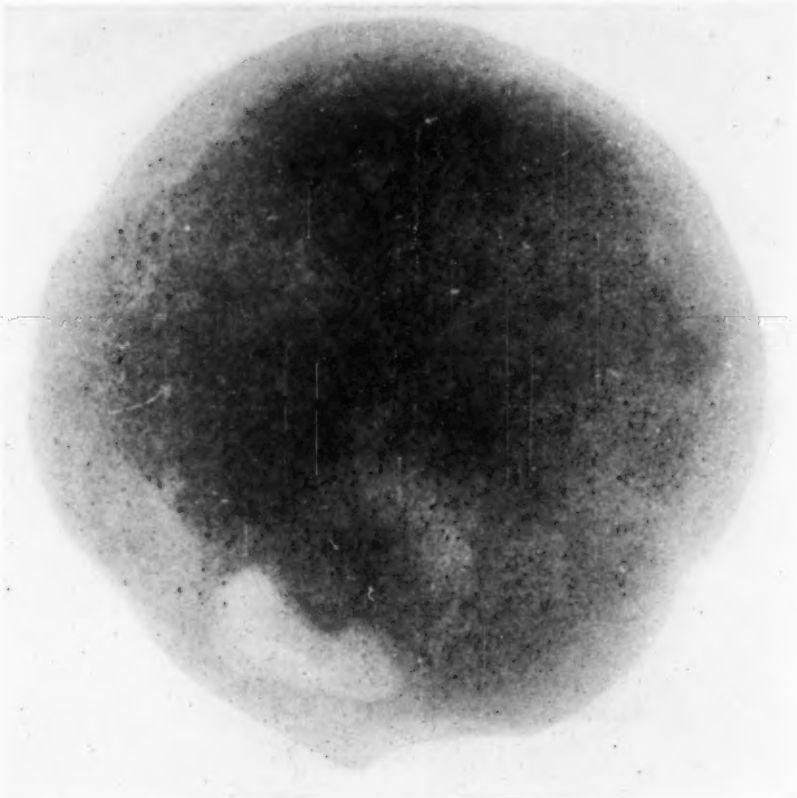

Figure 3. X-ray picture of the same dough in Figure 1 after being mixed three minutes.

Conclusions

If the properties of the flour will permit, it is advantageous to mix a dough in the Hobart-Swanson mixer for longer than one minute to completely incorporate the ingredients.

A two-minute mixing period was found to be sufficient for the thorough mixing of even very tough doughs.

THE ACTION OF ASCORBIC ACID AS A BREAD IMPROVER

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(Received for publication September 1, 1937)

In a paper dealing with a new conception of the role played by bromate and allied substances in panary fermentation, Jørgenson (1935) announced the discovery that ascorbic acid could act as a bread improver. In countries such as New Zealand where the addition of bromate to flour is illegal this discovery is of considerable potential importance since, although such improvers have to be used with caution on soft flours, there are occasions when the flour from certain areas or in certain seasons would benefit by their application.

During an investigation into the utility of lemon juice which is one of the cheapest and richest natural sources of ascorbic acid, it was discovered that the improving action did not decrease with age of the sample, despite the ready oxidizability of ascorbic acid by atmospheric oxygen. In one case a sample of lemon juice which was about six months old and which had practically no reducing power as measured by an iodine titration, was just as potent as a fresh sample. We were interested also in the apparent contradiction that whereas bromate, iodate, persulphate, etc., are strong oxidizing agents, ascorbic acid, with apparently the same action in panary fermentation, is a moderately strong reducing agent.

Experimental

Starting from the observation that lemon juice containing no reduced ascorbic acid was capable of acting in the same way as bromate, the first step was an investigation of the action of oxidized ascorbic or dehydroascorbic acid in panary fermentation. Dehydroascorbic acid was prepared by a simple iodine oxidation of ascorbic acid in aqueous solution, the oxidation being carried out immediately before addition to the dough. Results of volume determinations are given in Table I for two flours milled experimentally from New Zealand wheats and showing a large bromate response. The nitrogen figures for the two flours No. 53 and No. 203 were 2.40% and 2.24% respectively, figures considerably higher than the average for New Zealand wheats.

[1] National Research Scholar.

Only volumes are recorded in Table I, but other loaf characteristics exactly paralleled the differences in volume. Although results are given for only two flours, experiments with other flours with a large bromate response led to very similar results.

It may be seen from this table that bromate and dehydroascorbic acid have approximately the same improving action, weight for weight basis, and that dehydroascorbic acid is much more efficacious than is reduced ascorbic acid. In view of the easy oxidizability of ascorbic acid it was felt that these data were most easily explained on the hypothesis that ascorbic acid acts as a bread improver only in its oxidized form and that there exists in flour a mechanism whereby this oxidation can be easily effected.

In 1931 Szent-Györgyi showed that there exists in cabbage leaves an enzyme which he named hexoxidase and which acted as a catalyst in bringing about the change of ascorbic to dehydroascorbic acid in the

TABLE I

125 g. of flour, 2.5 g. of yeast, 2.5 g. of sugar, 1.8 g. of salt. 3 minutes mixing on a Hobart mixer. 4 hours 5 minutes from mixer to oven. Volume in cubic centimeters.

Laboratory Number	203	53
Basic formula	540	510
+ 5 mg. bromate	740	700
+ 5 mg. ascorbic acid	650	630
+ 5 mg. dehydroascorbic	730	720
+ 20 mg. ascorbic	700	—

presence of oxygen. Since that time it has been shown by Srinivasan (1936) and by Johnson and Zilva (1937) that hexoxidase or ascorbic acid oxidase is very widely distributed in nature and its presence in flour seemed quite probable.

To demonstrate this, straight-run flour was stirred into a paste with twice its weight of water, left overnight in an ice chest, the suspension centrifuged, and 50 c.c. of the supernatant liquid added to 6 mg. of ascorbic acid dissolved in 25 c.c. of water. The course of oxidation was followed by titration with 2 : 6 dichlorophenol indophenol, and it was found that after seven hours 89% of the ascorbic had been oxidized.

Concentration of the enzyme, using the directions of Szent-Györgyi, was then attempted. Thirteen hundred cubic centimeters of a flour-water extract were treated with ammonium sulphate to 30% saturation and the precipitate centrifuged off. The precipitate contained negligible amounts of ascorbic acid oxidase. The liquor was saturated with ammonium sulphate and the precipitate dissolved in

100 c.c. of M/15 phosphate buffer at pH 5. Fifty cubic centimeters of this solution were added to 10 mg. of ascorbic acid in 50 c.c. of water and the oxidation was followed by titration with 2 : 6 dichlorophenol indophenol. The rate of oxidation is given in Table II.

TABLE II

RATE OF OXIDATION OF ASCORBIC ACID

Time in hours	0	½	1	1½	2	2½	3	3½
Titre	5.10	4.54	3.96	3.42	2.77	2.15	1.63	1.05

Hence about 80% of the ascorbic acid was oxidized in 3½ hours, and the rate of oxidation is a linear function of time, a property of the enzyme clearly demonstrated by Hopkins and Morgan (1936). These same authors also show that ascorbic acid oxidase from cauliflower is inhibited by very small concentrations of cyanide, and it was found that the enzyme prepared from flour exhibits the same phenomenon. In the presence of M/1000 cyanide, with all other conditions the same as in the experiment already described, only 15.5% of the ascorbic had been oxidized at the end of four hours.

One further point remained to be proved, *viz.*, that the enzyme is capable of functioning as an oxidation catalyst during fermentation. For this purpose a concentrated enzyme solution was prepared from the florets of cauliflower, concentration and purification from any ascorbic acid which might be present being effected by fractionation with ammonium sulphate. A solution was used which had been kept for a week in the icebox and whose potency was such that 2 c.c. oxidized 5 mg. of ascorbic in 45 minutes.

TABLE III

RESULTS WITH FLOUR NO. 203

Flour number		Loaf volume in c.c.
203		540
203	+ 5 mg. ascorbic	650
203	+ 5 mg. iodine oxidised ascorbic	730
203	+ 10 c.c. enzyme solution	540
203	+ 5 mg. ascorbic + 10 c.c. enzyme	730
203	+ 5 mg. enzyme oxidized ascorbic [1]	740

[1] In this experiment the ascorbic was oxidized by ascorbic acid oxidase before being added to the dough.

Reversibly and Irreversibly Oxidized Ascorbic Acid

The instability of dehydroascorbic acid in aqueous solution at reactions higher than pH 4 has been stressed by a number of investi-

gators, and the irreversible and spontaneous change of dehydroascorbic acid to diketogulonic acid has been studied in detail by Borsook *et al.* (1937). In an endeavour to elucidate further the mechanism of ascorbic acid improvement the effect of diketogulonic acid was tried. The directions of Borsook for the preparation of this material, *viz.*, incubation of dehydroascorbic at pH 7 and 37° C., were followed. Reduction with hydrogen sulphide showed that only 5% of dehydroascorbic acid originally present remained in the reaction mixture.

The addition of this material to the dough gave no perceptible change in volume as compared with the control, so that the improving action can be narrowed down to the components of the reversible redox system of ascorbic-dehydroascorbic.

Discussion

The demonstration that dehydroascorbic acid is, on certain flours, a more efficient improver than is ascorbic acid, and that there exists in flour a mechanism whereby the oxidation of ascorbic to dehydroascorbic can take place, lends support to the hypothesis that ascorbic acid *per se* is inactive and that the improving action of this material is due entirely to its oxidation product. It will be noted that the two flours reported in Table I require comparatively high quantities of bromate in order to produce the best loaves of which they are capable, and that in these cases the effect of dehydroascorbic acid can not be duplicated by four times the amount of ascorbic acid. The case with flours requiring less bromate than 4 mg. per percent is otherwise. The difference between ascorbic acid and its oxidation product becomes much less marked and in certain cases disappears entirely. From experiments carried out on a range of flours, the only conclusion at which we have been able to arrive is that dehydroascorbic acid is always as potent as ascorbic acid and in the majority of cases is considerably more potent. On the basis of the hypothesis outlined above, this is not surprising since there are a number of variables involved in the oxidation, *e.g.*, variations in ascorbic acid oxidase content of different flours, which could account for such discrepancies.

Nevertheless the evidence, although suggestive, is by no means conclusive. We have extended our investigations, in an endeavour to test Jørgenson's theory of the effect of improvers on the proteolytic enzymes of flour, to the effect of ascorbic and dehydroascorbic acids on papain. While recognizing that such experiments are open to objections, it is of interest that preliminary results indicate that both ascorbic and dehydroascorbic acids inhibit papain, the latter to a greater degree than the former.

Summary

Dehydroascorbic acid is a bread improver which is equivalent to bromate on a weight for weight basis. On flours requiring relatively large quantities of bromate dehydroascorbic acid is more potent than ascorbic acid.

It has been shown that flour contains the enzyme ascorbic acid oxidase which is capable of catalyzing the oxidation of ascorbic acid to dehydroascorbic acid.

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OVEN SPRING OF DOUGH AS CORRELATED WITH CERTAIN PROPERTIES OF BREAD [1]

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(Read at the Annual Meeting, May 1937)

At the last annual meeting it was shown how the oven spring of dough was influenced by varying amounts of sugar, salt, and yeast. The present paper shows how oven spring is related to certain properties of bread when the sugar, salt, and yeast are held constant.

Materials

The wheats used in this study were varieties of hard red spring and hard red winter of the crop years 1933 and 1934. These included the more important recognized varieties together with a number of selections and crosses in both the spring and winter wheats. The varieties of the 1933 crop of spring wheats were Marquis, Ceres, Supreme, Red Bobs, Marquillo, Reliance, Komar, Hope, Reward, and Kota, while those of the 1934 spring wheat were Marquis, Supreme, Ceres, Thatcher, Hope, Reliance, and Reward. Because of the limited number of lots of winter wheat available, the crops of 1933 and 1934 were combined for the study. These varieties were Turkey, Nebraska No. 60, Karmont, Newturk, Yogo, Cheyenne, Minard, Montana 36, and Oro.

These wheats were grown in three locations in Montana under varying conditions of moisture as found on dry land and under irrigation. They were all well matured, were not subjected to freezing before harvest, nor were they damaged by sprouting in the field or by severe weathering. The weight per bushel ranged from 51 to 63 pounds for the 1933 spring wheat and from 49 to 63 pounds for the 1934 crop, while the range for the two crops of winter wheat combined was 55 to 63 pounds. The protein content of the 1933 spring wheat ranged from 10.00 to 18.50%, the 1934 spring wheat from 9.50 to 19.50%, and the winter wheat from 11.50 to 17.40%.

A 75% patent flour was made on an experimental mill by an experienced miller. A rather uniform extraction of flour was made, based on the test weight per bushel of wheat. The ash content of the flour was well under the 0.42% limit for patent flour.

[1] Contribution from Montana State College, Argicultural Experiment Station. Paper No. 93, Journal Series.

This method of securing material for the study of oven spring of dough in relation to certain properties of bread is believed to have been productive of flour having a wide range of strength and properties rather typical of Montana conditions.

Methods and Equipment

The Standard A. A. C. C. Baking Method as described in Cereal Laboratory Methods (1935) was used and the basic formula was employed with the following exceptions: Three percent sugar was used instead of 2.5%, and the dough was punched by passing it between canvas-covered sheeting rolls instead of folding by hand. The molding was also done with the sheeting rolls and the resulting strip of dough tightly rolled and folded for the pan. The baking pans used were the tall form.

Temperature control. The room temperature was kept within the limits of 23° to 26° C., and the dough when mixed had a temperature of approximately 30° C. This was accomplished by bringing the temperature of the flour to approximately 30° C. by placing it in the proofing cabinet over night and keeping the solutions at the following approximate temperatures before combining them in a beaker to add to the flour preparatory to mixing, *viz.:* sugar-salt solution, 40° C.; water, 40° C.; and yeast suspension, 30° C.

The dough was fermented and proofed at 30° ± 0.5° C. in a cabinet with revolving shelves as described by Whitcomb (1934). The thermometers in this cabinet revolved with the shelves.

The baking was done at 230° ± 5° C. in an oven with revolving shelves. A pan of water was kept in the oven.

Measuring oven spring. The oven spring was determined by measuring the height of the dough in the pan just before it was baked and again measuring the height of the resulting bread, the difference between these two readings being considered as oven spring. This was accomplished by placing the pan containing the dough, or the bread, on a base and sliding a projecting arm down to the topmost point, and reading the height in centimeters on the standard which supported the arm. This is illustrated in Figure 1.

The reliability which might be placed in the oven spring of dough when the same flour was used and the temperature and other conditions were held fairly constant was shown by Whitcomb (1936) in his study of the influence of sugar, salt, and yeast on oven spring. Based on the variation in oven spring of the check doughs which he baked, it was concluded that an accuracy of about 0.5 cm. might be expected.

Scoring the bread. The scoring of the bread was done in such a way as to provide suitable values for study and comparison. The

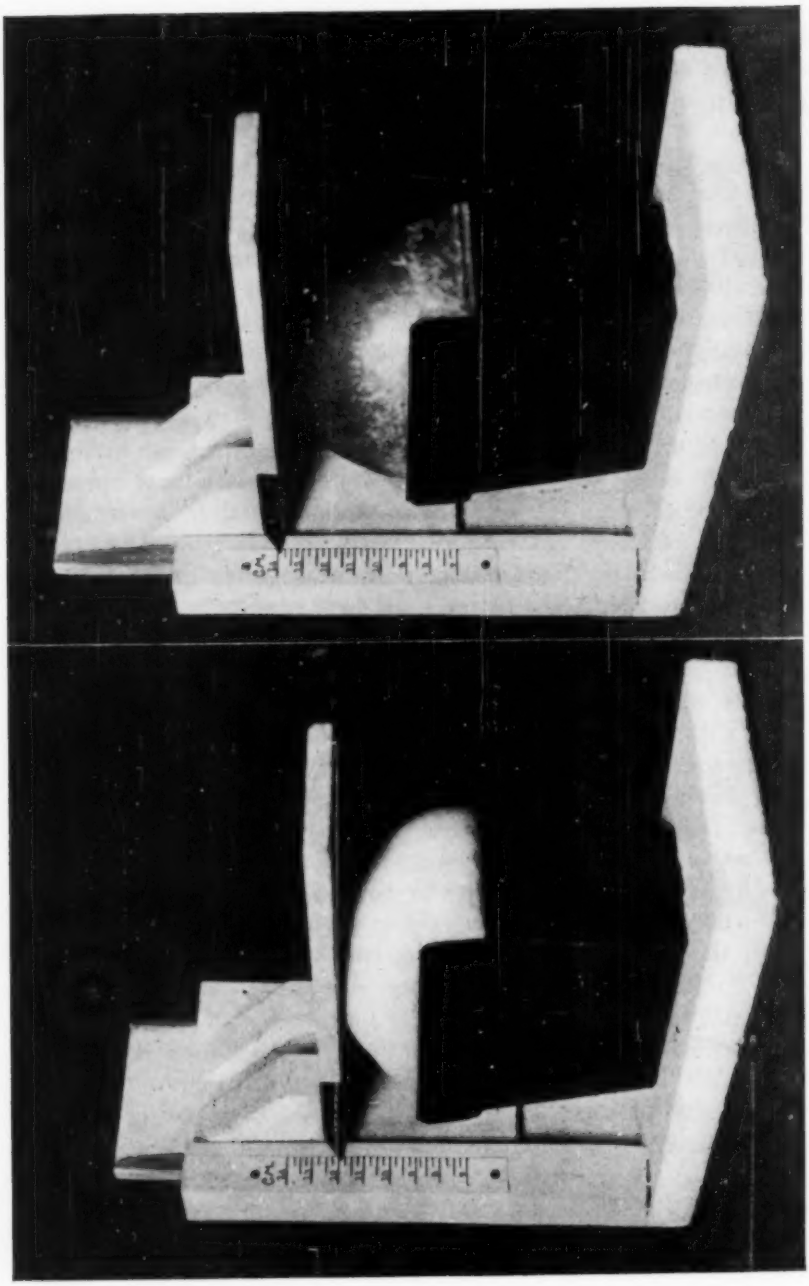

Figure 1. Oven spring measuring device. Left—Dough ready to place in oven. Right—Bread as it came from oven.

characteristics of crust color, boldness, and texture were scored on the basis of 100 as perfect. This standard was obtained by baking three check loaves from a good flour, made on a long system mill, with each day's baking. The color of crust was considered of importance as an indicator of the diastatic activity of the flour. However, a crust too dark in color was not considered desirable. Boldness of loaf is a term used to describe a loaf of well rounded appearance and one having a good shred and a lack of sagging at the ends and on the sides. The large loaves did not always have the best boldness. Boldness is referred to in the Standard Method as "symmetry." Texture took into consideration the size and shape of the cells of the cut surface of the bread and the thickness of the cell walls. The firmness of the bread was also a factor.

Results

The six characteristics of the wheat, flour, and bread which were studied in relation to the oven spring of the dough were loaf volume of bread, protein content of wheat, absorption of flour, color of crust of bread, boldness of loaf, and texture of bread. The statistical constants of mean, standard deviation, and coefficient of variability for the three lots of wheat under consideration are given in Tables I, II, and III.

TABLE I

STATISTICAL CONSTANTS FOR CERTAIN CHARACTERS OF WHEAT, FLOUR, AND BREAD—HARD RED SPRING—1933 CROP

Characters	Mean	Standard deviation	Coefficient of variability
Oven spring of dough, cm.	1.14± .02	.56± .02	48.90±1.79
Loaf volume of bread, cc.	561.50±2.07	48.73±1.46	8.68± .26
Protein content of wheat, %	14.84± .08	1.84± .06	12.40± .38
Absorption of flour, %	63.17± .11	2.51± .08	3.97± .12
Color of crust of bread, score	98.08± .09	1.99± .06	2.03± .06
Boldness of loaf of bread, score	97.72± .10	2.35± .07	2.42± .07
Texture of bread, score	98.53± .11	2.48± .08	2.52± .08

TABLE II

STATISTICAL CONSTANTS FOR CERTAIN CHARACTERS OF WHEAT, FLOUR, AND BREAD—HARD RED SPRING—1934 CROP

Characters	Mean	Standard deviation	Coefficient of variability
Oven spring of dough, cm.	1.23± .03	.57± .02	46.25±2.15
Loaf volume of bread, cc.	561.18±3.80	69.05±2.70	12.13± .48
Protein content of wheat, %	14.76± .14	2.48± .10	16.78± .66
Absorption of flour, %	61.09± .19	3.47± .13	5.67± .22
Color of crust of bread, score	97.47± .11	2.02± .08	2.07± .12
Boldness of loaf of bread, score	96.87± .17	3.08± .19	2.18± .12
Texture of bread, score	98.04± .15	2.71± .11	2.76± .11

TABLE III

STATISTICAL CONSTANTS FOR CERTAIN CHARACTERS OF WHEAT, FLOUR, AND BREAD—HARD RED WINTER—1933 AND 1934 CROPS COMBINED

Characters	Mean	Standard deviation	Coefficient of variability
Oven spring of dough, cm.	.60± .02	.37± .02	61.73±3.80
Loaf volume of bread, c.c.	510.18±2.13	32.44±1.50	6.36± .29
Protein content of wheat, %	13.83± .09	1.37± .64	9.91± .46
Absorption of flour, %	59.80± .28	4.29± .20	7.17± .33
Color of crust of bread, score	98.28± .08	1.26± .06	1.29± .06
Boldness of loaf of bread, score	93.73± .28	4.22± .20	4.51± .21
Texture of bread, score	95.64± .21	3.73± .17	3.90± .18

Variation of Characteristics as Shown by Statistical Constants

A comparison of chracteristics of the wheat, flour, and bread which were studied shows some interesting relationships.

Oven spring. The oven spring of the dough, as measured in centimeters, had an average of 1.14 and 1.23 for the 1933 and 1934 crops of spring wheat and 0.60 for the two crops of winter wheat when combined. This shows the spring wheat flour capable of producing a dough having about twice the oven spring of that of winter wheat flour. The range of the oven spring was from 0.0 to 2.75 for the 1933 spring wheat, 0.0 to 2.50 for the 1934 spring wheat, and 0.0 to 1.75 for the winter wheat. The percentage of the 1933 spring wheat having no oven spring of dough was 2.8, that of the 1934 spring wheat 1.3, and that of the winter wheat 7.5. This shows a condition comparable with that of the mean oven spring when the spring and winter wheats are compared. The variability of the oven spring for the spring and winter wheats is also of significance. As shown by the standard deviation, two-thirds of the lots of 1933 spring wheat fell in the range of 0.58 to 1.70 centimeters oven spring, while for the 1934 spring wheat it was 0.66 to 1.80, and for the winter wheat it was 0.23 to 0.97.

Protein of wheat. The mean protein contents of the spring wheat were 14.84 and 14.76% for the two crops while for the winter wheat as combined it was 13.83%. The standard deviations for the protein content each side of the mean were 1.84 and 2.48 for the spring wheats and 1.37 for the winter wheat.

Loaf volume. The mean loaf volumes of bread in cubic centimeters for the spring wheats were 561.50 and 561.18, respectively, and for the winter wheat 510.18, with standard deviations above and below these of 48.73 and 69.05 for the spring wheat and 32.44 for the winter wheat.

Absorption of flour. The mean absorptions of the spring wheat flours were 63.17 and 61.09%, while that for the winter wheat flour

was 59.80%. The standard deviations above and below these were 2.51 and 3.47 for the spring wheat and 4.29 for the winter wheat.

Color of crust of bread. The mean scores for the color of crust for the spring wheat were 98.08 and 97.47, and for the winter wheat 98.28. The standard deviations above and below these were 1.99 and 2.02 for the spring wheats and 1.26 for the winter wheat.

Boldness of loaf. The mean scores for boldness of loaf for the spring wheat were 97.72 and 96.87, respectively, while for the winter wheat it was 93.73. The standard deviations above and below these means were 2.35, 3.08, and 4.22, respectively.

Texture of bread. The mean scores for texture of the bread from spring wheat flour were 98.53 and 98.04 for the two lots and 95.64 for that from the winter wheat flour. The standard deviations about these means were 2.48, 2.71, and 3.73.

The coefficients of variability of the various characteristics of these three lots of wheat and the resulting flours and breads as shown in Tables I, II, and III are of significance in showing their relative variability. With this as a measure, it will be noted that the oven spring of dough was the most variable, with protein content of wheat next. The loaf volume of bread appeared to be more variable in the spring wheat than in the winter wheat.

Correlation of Oven Spring of Dough with Certain Properties of Bread and Flour

Oven spring of dough as measured in centimeters was correlated with loaf volume of bread, protein content of wheat, absorption of flour, color of crust of bread, boldness of loaf of bread, and texture of bread. The results of these studies for three lots of wheat are given in Table IV.

The correlation of oven spring with loaf volume gave plus coefficients, the magnitudes of which were 0.53 for the 1933 spring wheat, 0.51 for the 1934 spring wheat and 0.50 for the 1933 and 1934 combined crops of winter wheat. The coefficients of correlation for oven spring and protein content of wheat were + 0.32 and + 0.27 for the two lots of spring and − 0.05 for the combined crops of winter wheat, thus showing a lesser degree of agreement. The absorption of the flour was not definitely associated with oven spring as shown by the correlation coefficients of − 0.36, + 0.35, and − 0.26. The crust color of bread was positively correlated with oven spring for the spring wheats, the coefficients being + 0.21 and + 0.22, while it was negative for the winter wheat, the coefficient being − 0.02. Boldness of loaf was definitely associated with the oven spring of the dough to much the same degree as the volume of the loaf, the coefficients being + 0.56

and + 0.57 for the spring wheats and + 0.55 for the winter wheat. The texture of bread was also definitely correlated with the oven spring of the dough, though with somewhat smaller coefficients, the magnitudes of which were + 0.40 and + 0.31 for the spring wheat and + 0.50 for the winter wheat.

As a matter of comparison, the loaf volume of bread was correlated with the protein content of the wheat. There was a definite positive correlation for the spring wheat, while there was a very small negative correlation for the winter wheat, the coefficients being + 0.66 and + 0.62 for the spring wheat and − 0.04 for the winter wheat.

TABLE IV

COEFFICIENTS FOR CORRELATION OF OVEN SPRING OF DOUGH WITH CERTAIN PROPERTIES OF BREAD, AND FOR LOAF VOLUME OF BREAD WITH PROTEIN CONTENT OF WHEAT, FOR THREE LOTS OF WHEAT

Properties correlated	Hard red spring wheat 1933 crop (254 tests)	Hard red spring wheat 1934 crop (152 tests)	Hard red winter wheat 1933 and 1934 crops (106 tests)
Oven spring of dough with loaf volume of bread	.53±.03	.51±.04	.50±.05
Oven spring of dough with protein content of wheat	.32±.04	.27±.05	−.05±.07
Oven spring of dough with absorption of of flour	−.36±.04	.35±.05	−.26±.06
Oven spring of dough with color of crust of bread	.21±.04	.22±.05	−.02±.07
Oven spring of dough with boldness of loaf of bread	.56±.03	.57±.04	.55±.05
Oven spring of dough with texture of bread	.40±.04	.31±.05	.50±.05
Loaf volume of bread with protein content of wheat	.66±.02	.62±.03	−.04±.07

Discussion

The problem of associating certain properties of wheat and flour with those of the resulting bread has received attention by many investigators. The properties studied and the methods employed have varied considerably. The study of the oven spring of the dough in relation to certain properties of the bread and also to one property of the wheat and one of the flour is offered as a possible means of adding information of value. Dean and Swanson (1911) studied oven spring of dough in covered pans as influenced by fumigation of flour and concluded that it was not affected except in the low grade flour. Harrel (1926) studied the baking properties of flour as influenced by nine variables and noted that variation in fermentation period gave the most pronounced results in oven spring of dough. Whitcomb

(1936) studied the influence of sugar, salt, and yeast on the oven spring of dough with seven flours and concluded that both the flours and the ingredients had marked effects on the oven spring.

The variation of oven spring of dough, as shown in Tables I, II, and III, for flours from the spring and winter wheats would seem to have considerable significance when consideration is given to the baking properties of these two classes of wheat. The figures of 1.14 and 1.23 centimeters for the spring wheats as contrasted with 0.60 centimeters for the winter wheats are enough different to be of significance. It remains to be seen how this assumption works out when the oven spring of these two classes of wheat is correlated with some of the other properties of the bread.

As shown in Table IV, three of the correlation coefficients, in which oven spring is a part, for the winter wheat were negative and were of small order. These were when the factors of protein content of wheat, absorption of flour, and color of crust of bread were correlated with oven spring. These same coefficients for spring wheat were positive, except for absorption of flour for the 1933 crop of spring wheat which was − 0.36. On the other hand, the coefficients where oven spring was correlated with the factors of loaf volume, boldness of loaf, and texture of bread were all positive for both spring and winter wheat and were large enough to be of significance. A more detailed study of the correlations of oven spring with five of the properties of wheat, flour, and bread will be of interest.

Loaf volume of bread.[2] Perhaps more attention has been given to loaf volume and the factors affecting it than to any other property of bread baked in the experimental laboratory. The results of the present study, in which oven spring of dough is correlated with loaf volume and in which positive correlations of 0.50 or more have been obtained, compare favorably with those reported by other investigators. Blish and Sandstedt (1925) correlated loaf volume with viscosity of flour (unleached) and obtained a coefficient of + 0.245. When they correlated loaf volume with protein content of wheat, a coefficient of + 0.304 was obtained. Mangels (1926) studied correlation of loaf volume with protein content of hard red spring wheat for 11 crop years and reported coefficients ranging from − 0.014 to + 0.547. Hayes, Immer, and Bailey (1929) obtained correlations ranging from + 0.07 to + 0.50 for loaf volume and protein content of hard red spring wheat, and of − 0.52 and + 0.11 for hard red winter wheat. Bayfield (1934) studied baking properties of soft winter

[2] Note: In fairness to the investigators who published data on correlation of loaf volume with protein content prior to the adoption of the Standard A. A. C. C. Baking Test Method, it should be stated that better coefficients of correlation are to be expected with this improved method than with the old methods in use when the large loaf was baked.

wheats and reported correlations of loaf volume and protein of flour for the crop years of 1929 to 1932, ranging from + 0.4289 to + 0.8247. Later, Bayfield (1936) reported some correlation coefficients for protein of flour and loaf volume of bread in which tests were made on soft winter wheat flour both with and without bromate. For the 1931 crop, the coefficients were + 0.6397 without bromate and + 0.7707 with bromate. For the 1933 crop, the coefficients were + 0.6404 without bromate and + 0.7991 with bromate. These coefficients by Bayfield, even without bromate, which appear to be larger than those reported by other workers, may be explained by the fact that the wheat with which he worked may have had a higher diastatic activity, coming from a more humid region, than the wheat from the northwestern States. This also applies to the correlation coefficients for loaf volume and protein of wheat as reported in this study, which are + 0.66 and + 0.62 for spring wheat and − 0.04 for winter wheat.

Protein content of wheat. This correlation of oven spring of dough with protein content of wheat gave coefficients of + 0.32, + 0.27, and − 0.05, which compare rather favorably with the earlier correlations as given above for loaf volume and protein but not with the later ones as reported by Bayfield; however, these coefficients are not considered large enough to be of significance in the present study.

Absorption of flour. Absorption of flour in relation to baking properties has apparently received limited attention. The correlations of − 0.36, + 0.35, and − 0.26 for oven spring of dough and absorption of flour are not considered of significance.

Color of crust of bread. It was thought when this work was planned that a good correlation might be secured between oven spring of dough and color of crust of bread, as both of these properties are probably associated with the diastatic activity of the flour. But such was not the case, as indicated by the small coefficients of + 0.21 and + 0.22 for the spring wheats and − 0.02 for the winter wheat.

Boldness of loaf of bread. Although boldness of loaf of bread is not dependent upon the size of the loaf, slightly larger coefficients of correlation were secured between oven spring and this property than were obtained for oven spring and loaf volume. The coefficients in this case were + 0.56 and + 0.57 for the spring wheat and + 0.55 for the winter wheat. A correlation between boldness of loaf and texture of bread might be expected to give interesting results.

Texture of bread. Texture of bread in relation to loaf volume has received consideration by several investigators, and this study of texture in relation to oven spring of dough seems to be of equal importance. Hayes, Immer, and Bailey (1929) correlated loaf volume and texture of bread for four crop years of hard red spring wheat

and obtained coefficients of + 0.07, + 0.28, − 0.01, and + 0.40. The same correlations for two crop years of winter wheat gave coefficients of + 0.35 and − 0.03. Treloar, Sherwood, and Bailey (1932) correlated texture and loaf volume for six crop years of hard red spring wheat and obtained coefficients ranging from + 0.096 to + 0.329, with an average of + 0.188. In the light of the above results of correlation studies of loaf volume and texture of bread, the results of the present study in which oven spring was correlated with texture seem to be of special significance. These coefficients for oven spring and texture were + 0.40 and + 0.31 for spring wheat and + 0.50 for winter wheat. This association of oven spring and texture would seem to indicate that there are a number of factors in the dough which determine the texture of the bread and that the property of oven spring is but one of these. At least, a further study of this phase of the problem should yield some interesting results.

Summary

The oven spring of dough in relation to certain properties of wheat, flour, and bread is offered as a possible aid in the study of strength of flour and quality of bread.

Studies were made on the relation of oven spring of dough to protein content of wheat, absorption of flour, and the four properties of bread—loaf volume, color of crust, boldness of loaf, and texture.

The material used was selected from the 1933 and 1934 crops of hard red spring and hard red winter wheats grown in Montana.

The oven spring of dough from spring wheat flour averaged twice as much as that from winter wheat, being 1.4 centimeters for the former and 0.6 centimeters for the latter.

Oven spring of dough, when correlated with loaf volume of bread, gave significant coefficients of + 0.52 for spring wheat and + 0.50 for winter wheat. This indicated that good oven spring of dough was an important function in the production of a loaf of bread of good volume.

Oven spring of dough, when correlated with protein content of wheat, gave insignificant coefficients of + 0.30 for spring wheat and − 0.05 for winter wheat. This would seem to indicate that oven spring of dough from the flours studied was not dependent upon amount of protein. Protein content of wheat was, however, significantly correlated with loaf volume of bread for spring wheat but not for winter wheat.

Oven spring of dough, when correlated with absorption of flour, and independently with color of crust of bread, gave insignificant coefficients for both spring and winter wheats.

Oven spring of dough, when correlated with boldness of loaf of bread, gave coefficients of about the same order of significance as for oven spring and loaf volume. This was true for both spring and winter wheats.

Oven spring of dough and texture of bread were significantly correlated for winter wheat and fairly so for spring wheat.

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THE DETERMINATION OF SUGARS IN FLOUR

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In actual practice the accurate analysis of flour and dough is attended with great difficulties, especially in connection with the determination of carbohydrates.

The determination of these substances, representing about 90% of the total dry material of flour, is of great importance, for it enables us to follow the changes taking place in the dough during processing and is indicative of the progress of starch hydrolysis.

Review of Present Methods for Determination of Sugars in Flour

The presence of enzymes and micro-organisms in flour and dough makes it difficult to determine sugars with accuracy. Consequently the methods that have been developed for this purpose are of necessity based on the inhibition of the activity of enzymes and micro-organisms.

One of the oldest analytical methods for the determination of sugars in cereal products is the alcohol method adopted by the A. O. A. C. (1935). With this method alcohol is used to inhibit the activity of the enzymes and lead acetate is used for clarification. This method is inconvenient, time-consuming and expensive, and its use makes it more difficult to determine dextrins in the presence of sugar. Many attempts have therefore been made to solve the problem of determining sugars in flour and dough by using other means of inhibiting the activity of enzymes and micro-organisms.

Extraction with water at 0° C. has been attempted (see Blish, Sandstedt, and Astleford, 1932) but diastatic action was not completely stopped. The same is true of extraction with water at 0° C. to which sulfuric acid has been added as in the Rumsey (1922) procedure. Hermano and Rask (1926) tried phenol and chloroform as inhibitors, and also experimented with water containing sodium tungstate, both at room temperature and at 1° C.

These methods are based upon the inhibition of enzymes and micro-organisms in an acid medium (pH lower than the optimum). It is questioned whether partial hydrolysis of sugar and starch may not take place after prolonged action by the acid.

Methods of stopping enzyme action with the aid of a pH greater than the optimum, *i.e.*, with the aid of alkali, have thus far not given positive results (see Blish, Sandstedt, and Astleford, 1932), possibly due to the destructive action of alkali upon sugar.

At the Institute of Technology of Fermentation and Foods of the Warsaw Polytechnical School work was begun on the determination of sugars in alkaline solution, using ammonia as an inhibitor. It was found, however, that ammonia was not satisfactory, because starch was dissolved and enzymic action was not wholly inhibited.

A 0.2 N solution of sodium carbonate was then tried as a means of inhibiting enzyme action. This solution, however, attacked sugar and starch, and the quantity of sugar found in the extract differed from that found in an alcoholic extract. Accordingly a suitable concentration of the solution was sought which would completely inhibit the action of the enzymes without attacking the sugar and starch.

To this end experiments were made to determine the effect of sodium carbonate solutions on sugar alone, on sugar in flour extracts, on malt, and on 14 previously analyzed wheat and rye flours.

Influence of Different Concentrations of Sodium Carbonate and Bicarbonate upon Sugar in a Water Extract

In studying the effect of the alkaline solutions on sugar, only maltose and glucose were taken into consideration. Saccharose was omitted, as it is known that this sugar is not hydrolyzed by alkali.

First of all the effect of 0.2 N solutions of Na_2CO_3 and $NaHCO_3$ on maltose and glucose, the fundamental sugars of flour and dough, was determined.

The addition of Na_2CO_3 or $NaHCO_3$ increased the pH of the solution used for extraction. Changes in the concentration of sugar were determined by means of the Bertrand (1906) copper reduction method, and were checked by simultaneous observations with a saccharimeter. Duplicate determinations were made, both at room temperature and at 6° C., and the experiments were repeated several times.

For these determinations there were prepared solutions of 1 gram of sugar (maltose or glucose) in (*a*) 100 c.c. of a 0.2 N Na_2CO_3 solution and (*b*) 100 c.c. of 0.2 N $NaHCO_3$. Twenty cubic centimeters of these solutions were taken to determine the angle of rotation in a saccharimeter. After diluting the original solution in the proportion 1 to 5, 20 c.c. were used for determining reducing sugars by the Bertrand method.

The results of these experiments are recorded in Table I, the data there given being duplicate readings in each instance.

In these experiments with 0.2 N solutions of Na_2CO_3 and $NaHCO_3$, variations were observed both in the number of cubic centimeters of $KMnO_4$ required to reduce 20 c.c. of the alkaline sugar solutions and in the angle of rotation obtained with the saccharimeter, for glucose as well as maltose. It was evident that these solutions acted on the sugar. The nature of these changes was not investigated.

TABLE I

EFFECT OF 0.2 N Na_2CO_3—pH 10.48

Extraction time, hours	Temperature	Glucose: Angle of rotation in degrees		Glucose: C.c. $KMnO_4$ per 20 c.c. solution		Maltose: Angle of rotation in degrees		Maltose: C.c. $KMnO_4$ per 20 c.c. solution	
0	Room	3.3	3.3	7.71	7.71	7.5	7.5	3.81	3.81
5	"	2.9	2.9	7.59	7.59	7.2	7.2	3.85	3.85
10	"	2.8	2.8	7.58	7.58	7.0	7.0	3.80	3.80
0	"	3.1	3.1	8.29	8.30	7.5	7.5	4.38	4.40
5	"	3.0	2.9	8.39	8.39	7.3	7.3	4.31	4.31
20	"	2.9	2.9	8.40	8.40	7.2	7.3	4.25	4.25
0	"	3.0	3.0	8.18	8.15	7.5	7.5	3.80	3.82
5	"	3.0	3.0	8.20	8.20	7.5	7.5	3.95	3.95
10	"	2.9	2.9	7.76	7.78	7.5	7.5	3.85	3.85
EFFECT OF 0.2 N $NaHCO_3$—pH 8.76									
0	Room	3.3	3.3	7.62	7.62	7.3	7.3	3.60	3.60
5	"	3.3	3.3	7.62	7.62	7.2	7.2	4.09	4.09
10	"	3.1	3.1	7.60	7.60	6.9	6.9	3.78	3.78
20	"	3.0	2.9	8.57	8.57	7.5	7.6	4.36	4.36
0	6° C.	3.1	3.1	8.50	8.50	7.7	7.7	4.45	4.45
5	"	3.0	3.05	8.54	8.54	7.6	7.6	4.40	4.40
10	"	2.9	2.95	6.20	6.20	7.3	6.28	3.15	3.15

Effect of 0.2 N Solutions of Na_2CO_3 and $NaHCO_3$ upon Sugar in a Flour Extract

The fact that both of these alkali solutions acted on both glucose and maltose in aqueous solutions indicated that the pH was too high. The next point investigated therefore was whether the natural acidity of flour would reduce the pH of an extract of flour made with 0.2 N Na_2CO_3 or $NaHCO_3$ to such an extent that sugar dissolved in the extract would not be decomposed. The following experiments were therefore made.

Ten grams of glucose or maltose were added to a suspension of 50 g. of flour in 1 liter of 0.2 N Na_2CO_3 or $NaHCO_3$ in a Stohman flask and the suspension shaken for 2 hours in a mechanical shaker, on the assumption that in this length of time the soluble components of the

flour would be completely extracted. Five grams of filtering asbestos (Schering-Kahlbaum No. 07773) were then added and the suspension filtered onto a Büchner funnel, using an S. & S. No. 572½ filter paper. The filtrate was clarified by adding 2 drops of basic lead acetate and a pinch of animal carbon (*Carbo animalis purrisimus*, Merck, No. 2184E) and refiltering. By means of a pipette, 20 c.c of the filtrate were transferred to a 100 c.c. volumetric flask and made up to the mark with 0.2 N Na_2CO_3 or $NaHCO_3$. Portions of this solution were taken for the determination of sugar by the Bertrand method and for the measurement of the angle of rotation in the saccharimeter. The determinations made after 2 hours' shaking were taken as zero time. Similar suspensions were allowed to stand for 5 hours and 20 hours after shaking, and were then filtered and clarified in the manner just described. All these experiments were repeated three times. The results are shown in Table II. Figures for duplicate determinations are given.

TABLE II

EFFECT OF 0.2 N Na_2CO_3 AND $NaHCO_3$ UPON GLUCOSE AND MALTOSE ADDED TO FLOUR EXTRACTS

Sugar	Time in hours	0.2 N Na_2CO_3—pH 10.48				0.2 N $NaHCO_3$—pH 8.76			
		C.c. $KMnO_4$ per 20 c.c. solution		Angle of rotation in degrees		C.c. $KMnO_4$ per 20 c.c. solution		Angle of rotation in degrees	
Glucose	0	6.70	6.70	2.4	2.4	6.70	6.70	2.6	2.6
"	5	6.75	6.75	2.3	2.3	6.90	6.90	2.2	2.2
"	20	6.75	6.75	2.3	2.3	6.93	6.93	2.2	2.2
Maltose	0	3.34	3.34	5.5	5.5	3.68	3.68	6.2	6.2
"	5	3.35	3.35	5.5	5.5	3.49	3.49	5.5	5.5
"	20	3.30	3.30	5.5	5.5	3.49	3.49	5.5	5.5

These experiments proved that the acidity of the flour did not reduce the pH of an alkaline extract sufficiently to prevent changes in the sugars. The changes continue, though at a considerably slower rate. It was observed that the changes that took place with increasing time were smaller with Na_2CO_3 than with $NaHCO_3$. For purposes of orientation, the following figures are given on the pH of the various extracts containing glucose and maltose:

(1) 0.2 N Na_2CO_3 flour extract + glucose ..... pH 10.40
(2) 0.2 N Na_2CO_3 flour extract + maltose ..... pH 10.44
(3) 0.2 N $NaHCO_3$ flour extract + glucose ..... pH 8.59
(4) 0.2 N $NaHCO_3$ flour extract + maltose ..... pH 8.73

The above differences in pH may be caused by the action of the enzymes or by the destructive action of the alkaline solution on the sugars.

The 0.2 N Na_2CO_3 flour extract was examined for mannose, and the phenylhydrazone of mannose was found, indicating the presence of mannose, which is the result of the isomerization of glucose, this being the first stage of the action of the alkali. As stated in the foregoing, these alterations in the sugars may be brought about by too high a pH. In order to avoid this destructive influence, we used in our further experiments a mixture consisting of 75% of 0.2 N Na_2CO_3 and 25% of 0.2 N $NaHCO_3$.

Experiments with this mixture were made by the same procedure as before, except that instead of animal carbon, "Celite" was used to decolorize the filtrate. This change was dictated by the belief that carbon absorbs a portion of the sugar, especially maltose, which has a relatively large molecule, whereas "Celite" is used in sugar refineries and has proved to be efficient.

The results obtained with the mixture of Na_2CO_3 and $NaHCO_3$ in flour extracts containing added sugar are shown in Table III. Figures for duplicate determinations are given.

TABLE III

EFFECT OF MIXTURE CONTAINING 75% 0.2 N Na_2CO_3 AND 25% 0.2 N $NaHCO_3$ UPON ADDED SUGARS IN FLOUR EXTRACTS

Sugar	Temperature	Time in hours	C.c. $KMnO_4$ per 20 c.c. solution		Angle of rotation in degrees	
Glucose	Room	0	6.55	6.55	1.9	1.9
"	"	5	6.55	6.55	1.9	1.9
"	"	20	6.65	6.65	1.9	1.9
"	6° C.	0	7.32	7.32	3.1	3.1
"	"	5	7.27	7.27	3.1	3.1
"	"	22	7.27	7.27	3.1	3.1
Maltose	Room	0	3.36	3.36	7.4	7.4
"	"	5	3.36	3.36	7.4	7.4
"	"	20	3.38	3.38	7.4	7.4
"	6° C.	0	3.99	3.99	7.45	7.45
"	"	5	3.85	3.85	7.45	7.45
"	"	20	3.85	3.85	7.45	7.45

The destructive effect of alkali on sugar was lessened by using the mixed soda solution. As changes occurred in the sugars during the first few hours, it was desirable to find out what happened to the maltose during the first two hours of shaking. In the previous experiments the first measurements were made after two hours of shaking the maltose with the soda solution and the flour. It was desired to determine whether the constancy of the values for maltose indicated that the mixed soda solution did not act on maltose or whether it was the result of equilibrium during the first two hours.

A series of experiments was made using the same method as before, and the changes that took place in the sugar after 0, 2 and 20 hours at room temperature were studied. Again differences were found in the sugar in the extract after various times, pointing to the fact that the quantity or quality had undergone change. The relative constancy of the results for maltose in the preceding experiments was therefore the result of equilibrium within the first two hours. The same can be said of glucose.

The differences observed may be the result of—

(1) The action of enzymes
(2) The action of micro-organisms
(3) The destructive effect of the mixed soda solution on sugars.

Because of the high pH it does not seem likely that enzymatic action is a factor; the fact that the changes were observed chiefly during the first hours testifies against the supposed action of micro-organisms. Nevertheless it was decided to investigate the effect of an increase in concentration upon the values obtained.

For this purpose a solution of 75% of 0.3 N Na_2CO_3 and 25% of 0.3 N $NaHCO_3$ was used, under exactly the same conditions as in previous experiments. In all the experiments the differences in the values obtained increased for both glucose and maltose.

Thus the use of higher concentrations of the soda mixture was shown to be valueless, as it brings about considerable destruction of sugar.

Effect of Lower Concentrations of the Soda Mixture

Lower concentrations of the soda mixture were therefore tried, and a number of tests were run with different concentrations. It was found that a mixture of 75% of 0.15 N Na_2CO_3 and 25% $NaHCO_3$ was suitable for the purpose, as it does not change the composition of the sugars in an aqueous solution while it does inhibit enzymatic action.

The results of replicate tests are given in Table IV. The determinations made after 20 hours are omitted, as the earlier experiments showed no significant differences between the measurements after 5 and after 20 hours.

By using this concentration the maltose does not undergo any change that could be detected; on the other hand, considerable differences appear in the figures for glucose. One may assume that: (1) This concentration does not act on maltose but does attack glucose, (2) the enzymes are still active, and (3) the micro-organisms are still active. The second supposition may be rejected because the high pH excludes the possibility but the third is quite probable.

TABLE IV

EFFECT OF MIXTURE CONTAINING 75% 0.15 N Na_2CO_3 AND 25% 0.15 N $NaHCO_3$ UPON ADDED SUGARS IN FLOUR EXTRACTS

Sugar	Temperature	Time in hours	C.c. $KMnO_4$ per 20 c.c. of solution				Angle of rotation in degrees			
Glucose	Room	0	7.60	7.60	7.60	7.60	2.2	2.2	2.2	2.1
"	"	2	7.53	7.53	7.53	7.53	2.1	2.1	2.1	2.1
"	"	5	7.38	7.38	7.38	7.38	2.1	2.1	2.1	2.1
"	6° C.	0	7.60	7.60	7.60	—	2.2	2.1	—	—
"	"	2	7.38	7.38	7.38	—	2.1	2.1	—	—
"	"	5	7.38	7.38	7.38	—	2.1	2.1	—	—
Maltose	Room	0	4.00	4.00	4.00	4.00	6.3	6.3	6.3	6.3
"	"	2	4.00	4.00	4.00	4.00	6.3	6.3	6.3	6.3
"	"	5	4.00	4.00	4.00	4.00	6.3	6.3	6.3	6.3
"	6° C.	0	4.10	4.11	4.11	—	6.3	6.3	—	—
"	"	2	4.12	4.11	4.12	—	6.3	6.3	—	—
"	"	5	4.12	4.12	4.12	—	6.3	6.3	—	—

Effect of Adding Chloroform to the Soda Mixture

For this reason experiments were made in which chloroform was added in the process of shaking, as a means of checking the activity of micro-organisms. Our conjecture as to the action of micro-organisms proved to be correct. At room temperature the differences obtained were so insignificant that it would not be far wrong to say that the chloroform had checked the action of the micro-organisms. At the temperature of an icebox, viz., 6° C., the results obtained with the above concentration in the presence of chloroform were stable, from which it was inferred that the enzymatic and biological processes were completely checked.

The results of the experiments are shown in Table V. Replicate tests are given in each instance.

TABLE V

EFFECT OF ADDED CHLOROFORM UPON ACTION OF SODA MIXTURE (0.15 N) ON ADDED SUGARS IN FLOUR EXTRACTS

Sugar	Temperature	Time in hours	C.c. $KMnO_4$ per 20 c.c. of solution				Angle of rotation in degrees			
Glucose	Room	0	7.50	7.50	7.50	7.50	2.2	2.2	2.2	2.2
"	"	2	7.49	7.49	7.49	7.49	2.2	2.2	2.2	2.2
"	"	5	7.49	7.49	7.49	7.49	2.2	2.2	2.2	2.2
"	6° C.	0	7.30	7.30	7.30	7.30	2.2	2.2	2.2	2.2
"	"	2	7.28	7.30	7.30	7.30	2.2	2.2	2.1	2.2
"	"	5	7.30	7.30	7.30	7.30	2.2	2.2	2.2	2.2
Maltose	Room	0	4.00	4.00	4.00	4.01	6.3	6.4	6.3	6.4
"	"	2	4.00	4.00	4.00	4.00	6.4	6.4	6.4	6.4
"	"	5	3.98	3.98	3.98	3.98	6.4	6.4	6.4	6.4
"	6° C.	0	4.06	4.06	—	—	6.1	6.1	—	—
"	"	2	4.08	4.06	—	—	6.1	6.1		
"	"	5	4.06	4.08	—	—	6.1	6.1	—	—

Proof is thus furnished that the mixture of 0.15 N solutions of Na_2CO_3 and $NaHCO_3$ with the addition of a few drops of chloroform is suitable for the determination of the sugars in flour, because it completely checks the action of enzymes and micro-organisms and at the same time does not attack sugar. The pH of the mixture itself was measured electrometrically and found to be 9.85.

Examination of Flour Extracts with the Refractometer

It remained to be settled whether this mixture did not attack starch and thus change the concentration of the extract. To this end experiments were made to determine whether the concentration of the flour extracts studied did not change with the course of time. At intervals of one hour, measurements were made of the refractive index of flour extracts by means of an Abbe refractometer. Under these conditions a change in the refraction could only be caused in consequence of the hydrolysis of starch, and would not be due to a change in the composition of the sugars already present in the solution.

The experiments were conducted as follows:

Fifty grams of flour were placed in a 1-liter Stohman flask and made up to the mark with a mixture of 75% 0.15 N Na_2CO_3 and 25% 0.15 N $NaHCO_3$, to which a few drops of chloroform had been added. The contents were shaken for 2 hours. After adding filtering asbestos, part of the extract was taken for refractometric measurements and the balance was left on the flour and stored in an ice-box for later measurements. For purposes of comparison, parallel tests were made, using distilled water for extraction. One of the soda-mixture extracts was kept in an ice-box together with the water extract, while the others were kept at room temperature (+ 20° C.). The results of the experiments are shown in Tables VI and VII. Duplicate readings were made with each experiment.

To complete the data the refractive index of distilled water was determined and found to be 1.3321, and the refractive index of the soda mixture was found to be 1.3341.

The results set forth in Table VI show that no change in the refractive index occurs as the extraction time is increased, proving that the concentration of the extract does not change. It may therefore be concluded that the soda mixture used for the extraction of the flour does not disintegrate starch. As a further check on the previous experiment, more concentrated extracts were made up with the soda mixture, using 100 and 200 grams of flour per liter. It was found that regardless of the concentration, the refractive index of the extract did not change as the extraction time was increased.

TABLE VI

INFLUENCE OF 0.15 N SODA MIXTURE WITH CHLOROFORM UPON REFRACTIVE INDEX OF FLOUR EXTRACTS

Type of flour	Time in hours	Index of refraction (duplicate readings)		Type of flour	Time in hours	Index of refraction (duplicate readings)	
Rye, 40% extraction (Grasberg Mill, Warsaw)	0	1.3351	1.3351	Wheat, Steinmetz process	0	1.3344	1.3344
	1	1.3351	1.3351		1	1.3344	1.3344
	2	1.3351	1.3351		2	1.3344	1.3344
	3	1.3351	1.3351		3	1.3344	1.3344
	4	1.3351	1.3351		4	1.3344	1.3344
	5	1.3351	1.3351		5	1.3344	1.3344
	6	1.3351	1.3351		6	1.3344	1.3344
Rye, 55% extraction, type 00/1 (Wichert Mill, Starograd)	0	1.3350	1.3350	Wheat, Perla Pomorska, G. L. 100	0	1.3328	1.3328
	1	1.3350	1.3350		1	1.3328	1.3328
	2	1.3350	1.3350		2	1.3328	1.3328
	3	1.3350	1.3350		3	1.3328	1.3328
	4	1.3350	1.3350		4	1.3328	1.3328
	5	1.3350	1.3350		5	1.3328	1.3328
	6	1.3350	1.3350		6	1.3328	1.3328
Rye, 65% extraction, type 00 (Wichert Mill, Starograd)	0	1.3349	1.3349	Wheat (Wenus Steam Mill)	0	1.3346	1.3346
	1	1.3349	1.3349		1	1.3346	1.3346
	2	1.3349	1.3349		2	1.3346	1.3346
	3	1.3349	1.3349		3	1.3346	1.3346
	4	1.3349	1.3349		4	1.3346	1.3346
	5	1.3349	1.3349		5	1.3346	1.3346
	6	1.3349	1.3349		6	1.3346	1.3346
Rye, 40% extraction, "Extra," (Torun Mill)	0	1.3352	1.3352	Wheat (Warsaw Mill)	0	1.3346	1.3346
	1	1.3352	1.3352		1	1.3346	1.3346
	2	1.3352	1.3352		2	1.3346	1.3346
	3	1.3352	1.3352		3	1.3346	1.3346
	4	1.3352	1.3352		4	1.3346	1.3346
	5	1.3352	1.3352		5	1.3346	1.3346
	6	1.3352	1.3352		6	1.3346	1.3346
				Wheat, 60% extraction (Wichert Mill, Starograd)	0	1.3350	1.3350
					1	1.3350	1.3350
					2	1.3350	1.3350
					3	1.3350	1.3350
					4	1.3350	1.3350
					5	1.3350	1.3350
					6	1.3350	1.3350

As the figures of Table VII indicate, the index of refraction changes as the extraction time is increased when the flour is extracted with water, showing that the concentration of the extract has changed. At a temperature of 8° C. the change is less than at 30° C., because the enzymes are less active at the lower temperature. Increasing the concentration of the extract (Table VII A) by increasing the amount of flour up to 200 grams per liter resulted in a decided change in the values obtained.

In order to obtain more complete evidence as to the value of the soda-mixture extraction method for the determination of sugars in flour, several supplementary experiments were undertaken.

TABLE VII

REFRACTIVE INDEX OF WATER EXTRACTS OF FLOUR

Effect of temperature					
Type of flour	Temperature of extraction in ° C.	Time of extraction, hours	Grams of flour per liter	Index of refraction (duplicate readings)	
Rye, 40% extraction (Grasberg Mill, Warsaw)	8	0	50	1.3338	1.3338
		1		1.3341	1.3341
		2		1.3342	1.3342
		3		1.3342	1.3343
		4		1.3343	1.3343
		5		1.3343	1.3343
		6		1.3343	1.3344
Rye, 40% extraction (Grasberg Mill, Warsaw)	30	0	50	1.3336	1.3336
		1		1.3337	1.3337
		2		1.3334	1.3334
		3		1.3336	1.3336
		4		1.3340	1.3340
		5		1.3341	1.3341
		6		1.3344	1.3344
Rye, 40% extraction, "Extra," (Toruń Mill)	8	0	50	1.3339	1.3339
		1		1.3341	1.3341
		2		1.3341	1.3342
		3		1.3342	1.3342
		4		1.3342	1.3342
		5		1.3343	1.3342
Rye, 40% extraction, "Extra," (Toruń Mill)	30	0	50	1.3331	1.3331
		1		1.3334	1.3334
		2		1.3334	1.3334
		3		1.3335	1.3335
		4		1.3336	1.3336
		5		1.3336	1.3337

In a fermenting dough the enzymatic processes proceed at a rapid rate, and in order to carry out a determination of sugar one must work fast and stop the enzymatic action completely. In order to test out the method under extreme conditions, the mixture consisting of 75% of 0.15 N Na_2CO_3 and 25% of 0.15 N $NaHCO_3$ and containing a few drops of chloroform was allowed to act on malt for 5 hours, and the changes in the concentration of the extract with increasing extraction time were determined with the refractometer.

Fifty grams of dry malt in a Stohman flask were made up to the mark with the soda mixture and shaken for two hours in a mechanical shaker. After the addition of filtering asbestos, part of the extract was filtered off and its refractive index determined, while the remainder was held at 8° C. or 30° C. for further testing. For purposes of comparison parallel tests were run, using distilled water instead of the soda mixture. The results are given in duplicate in Table VIII.

TABLE VII A

Effect of concentration			
Type of flour	Time of extraction, hours	Grams of flour per liter	Index of refraction
Wheat, "Standard B," (Mill of Warsaw)	0	50	1.3330
	1		1.3330
	2		1.3330
	3		1.3332
	4		1.3345
	5		1.3345
Wheat, "Standard B," (Mill of Warsaw)	0	100	1.3338
	1		1.3339
	2		1.3339
	3		1.3345
	4		1.3338
	5		1.3338
Wheat, "Standard B," (Mill of Warsaw)	0	200	1.3337
	1		1.3338
	2		1.3339
	3		1.3348
	4		1.3355
	5		1.3355
	24		1.3357

TABLE VIII

REFRACTIVE INDEX OF MALT EXTRACT

Extraction medium	Temperature of extraction in °C.	Time in hours	Index of refraction (Two sets of duplicate readings)			
Soda mixture	8	0	1.3359	1.3359	1.3360	1.3360
		1	1.3361	1.3361	1.3365	1.3365
		2	1.3361	1.3361	1.3368	1.3368
		3	1.3361	1.3361	1.3368	1.3368
		4	1.3361	1.3361	1.3369	1.3369
		5	1.3362	1.3362	1.3369	1.3369
Distilled water	8	0	1.3339	1.3339	1.3339	1.3339
		1	1.3345	1.3345	1.3344	1.3344
		2	1.3349	1.3349	1.3349	1.3349
		3	1.3350	1.3350	1.3349	1.3349
		4	1.3352	1.3352	1.3352	1.3352
		5	1.3352	1.3352	1.3352	1.3352
Distilled water	30	0	1.3341	1.3341	1.3340	1.3340
		1	1.3350	1.3350	1.3348	1.3348
		2	1.3352	1.3352	1.3349	1.3349
		3	1.3354	1.3354	1.3349	1.3349
		4	1.3355	1.3355	1.3350	1.3350
		5	1.3358	1.3358	1.3352	1.3352

A malt and flour extract, prepared from 10 grams of malt and 40 grams of 40% extraction rye flour (Grasberg Mill, Warsaw) in one liter of soda mixture, was also tested. The figures are given in Table IX.

The changes that occurred in the soda-mixture extract of the mixture of flour and malt are so small in comparison with those which occurred in the water extract that they can be considered as of no practical importance. The difference in the extracts after 4 or 5 hours suggests that in this case, due to the lowering of the pH by the acidity of the malt, the activity of the enzymes was not completely checked, but was slowed down to such an extent that no differences were noted during the first hours of extraction.

TABLE IX

REFRACTIVE INDEX OF EXTRACTS OF FLOUR AND MALT

Nature of extract	Temperature of extraction in ° C.	Time in hours	Index of refraction (duplicate readings)	
Soda mixture	8	0	1.3339	1.3339
extract of		1	1.3340	1.3340
rye flour		2	1.3340	1.3340
and malt		3	1.3340	1.3340
		4	1.3340	1.3340
		5	1.3341	1.3341
Distilled water	30	0	1.3339	1.3339
extract of		1	1.3340	1.3340
rye flour		2	1.3340	1.3340
and malt		3	1.3341	1.3341
		4	1.3343	1.3343
		5	1.3345	1.3345

Effect of the Soda Mixture with Chloroform upon the Activity of Micro-organisms

Having studied the effect of the mixture consisting of 75% of 0.15 N Na_2CO_3 and 25% of 0.15 N $NaHCO_3$, with a few drops of chloroform, upon enzymatic activity, it remained to be determined how this mixture affected the viability of micro-organisms present in the flour extract.

As a nutritive medium for fungi, gelatine was used, made up with water and with soda-mixture extracts of malt and flour. A 10% solution of unhopped malt extract was used as a nutritive medium for bacteria.

The extracts were prepared from flour and malt by the above-described method, using 50 grams of flour or malt made up to one liter with soda mixture or water.

Seeding was carried out at dilutions of approximately 1, 1:10 and 1:100, designated respectively as I, II and III. The infected nutritive medium was poured into sterile Petri dishes 10 cm. in diameter. The dishes were placed in an incubator and examined after 24, 48 and 72 hours.

The data recorded in Table X show the numbers of colonies of molds, yeasts and bacteria that grew in various times and at different

TABLE X

GROWTH OF MOLDS, YEASTS AND BACTERIA ON SUBSTRATES PREPARED WITH WATER AND SODA-MIXTURE EXTRACTS OF FLOUR AND OF MALT

Extraction time, hours	Dilution	Soda-mixture extract of wheat flour			Water extract of wheat flour			Soda-mixture extract of malt			Water extract of malt		
		24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.	24 hrs.	48 hrs.	72 hrs.
0	I	—	—		2	—	8	16	—	4	—	1 mold	Molded
0	II	—	—	1	—	Part liq.[1]	6 4 pl.	—	—	Liq.	—	Small colony	Great no. of col.
0	III	—	—	—	—	—	3 mold	—	—	1 mold	—	—	4
2	I	—	—	—	—	Part liq.	Liq.	—	—		—	12	Liq., great no. of col.
2	II	—	—	—	—	—	Liq.	—	—	—	—	Liq.	Liq., great no. of col.
2	III	—	—	—	—	4 mold	Liq.	—	—	—	—	—	32
4	I	—	—	3	—	10	Mold	—	—	—	—	Great no. of col.	Liq., great no. of col.
4	II	—	—	—	—	—	14	—	—	—	—	2	Liq., great no. of col.
4	III	—	—	—	—	Part liq.	5	—	—	—	—	2	Liq.
6	I	—	—	—	—			—	1 mold	3	—	—	
6	II	—	—	—	—	—		—	—	—	—	15	—
6	III	—	—	—	—	—	—	—	—	—	—	—	—
24	I	—	—	—	—	—	3	—	—	—	—	—	—
24	II	—	—	—	—	—	11	—	—	—	—	—	—
24	III	—	—	—	—	—	1	—	—	—	—	—	—

[1] Liquefied.

dilutions on substrates prepared with water and soda-mixture extracts of flour and of malt. The minus sign indicates that no colonies were present.

These tests were repeated with four kinds of flour and two kinds of malt. A survey of all the data has led to the conclusion that a mixture consisting of 75% of 0.15 N Na_2CO_3 and 25% of 0.15 N $NaHCO_3$, with a few drops of chloroform, completely checks the growth of

micro-organisms, as a substrate infected with a flour or malt extract prepared with such a mixture generally remains sterile, whereas on a substrate infected with a water extract the micro-organisms develop very readily. This confirms the findings of the previous experiments.

Electrometric Determinations of pH in Solutions and Extracts

In order to record complete information as to the conditions existing during the foregoing experiments, the pH of the solutions and extracts used was determined at the same time. The results of these measurements are given in Table XI.

TABLE XI

pH of Solutions and Extracts Used in the Experiments

	Potential, millivolts	pH
0.2 N Na_2CO_3	868.1	10.48
0.2 N $NaHCO_3$	768.3	8.76
0.2 N Na_2CO_3 extract of—		
Flour + glucose	863.8	10.40
Flour + maltose	866.4	10.44
0.2 N $NaHCO_3$ extract of—		
Flour + glucose	758.5	8.56
Flour + maltose	766.8	8.73
0.2 N soda-mixture extract of—		
Flour + glucose	855.1	10.25
Flour + maltose	857.1	10.29
0.3 N soda-mixture extract of—		
Flour + glucose	853.9	10.23
Flour + maltose	850.7	10.18
0.15 N soda-mixture extract of—		
Flour + glucose	850.0	10.16
Flour + maltose	851.8	10.20
0.15 N soda-mixture extract of—		
40% rye flour (Warsaw Mill)	850.0	10.16
55% rye flour (Wichert Mill)	846.2	10.10
65% rye flour (Wichert Mill)	847.4	10.12
Steinmetz flour	841.8	10.02
40% rye flour (Toruń Mill)	847.3	10.12
Rye flour (Frydrychewicz Mill)	844.6	10.07
Buffer mixture (Equal parts of M/15 Na_2HPO_4 and M/15 KH_2PO_4)	653.6	6.81

Conclusions

The experiments described in the foregoing have led to the conclusion that a mixture consisting of 75% of 0.15 N Na_2CO_3 and 25% of 0.15 N $NaHCO_3$, containing a few drops of chloroform, is suitable as an extraction medium (at 6° C.) for the determination of sugars in flour. The concentrations of carbonates used do not destroy the sugars pre-existing in the flour, do not decompose the starch or protein materials, and completely check the activity of enzymes and micro-organisms. In comparison with other methods, this method is cheaper, simpler, and requires less time for extraction. It permits extraction

with an aqueous solution which is much cheaper than the alcohol used in other methods.

No other method of this nature has been described in the literature. In all the other methods the extractions are carried out in an acid medium.

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A COMPARISON OF THE LONG AND SHORT GASSING POWER METHODS[1]

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(Read at the Annual Meeting, May 1937)

In 1933 Sandstedt and Blish introduced the pressuremeter for measuring the gas-producing power of dough. This device offered many advantages for such tests but had the rather serious disadvantage of requiring 4 to 6 hours to obtain the best results. The recent modification introduced by Sandstedt (1937) gives pressuremeter values at 2 and 3 hours which are thought to identify more thoroughly important factors of gas production in dough. This report is a summary and comparison of results obtained by the long- and short-time pressuremeter methods on forty samples of commercial flour selected to offer a wide range of gas-production values.

The 6-hour pressuremeter figures were obtained by mixing 10 g. of flour and 10 c.c. of distilled water in which was suspended 0.3 g. of fresh yeast. For the 2-hour and 3-hour pressuremeter values, 10 g. of flour were mixed with 10 c.c. of distilled water in which were suspended .5 g. of fresh yeast and .5 g. of yeast activator.[2] The diastatic activity values as determined by the Blish and Sandstedt (1933) ferricyanide method were also obtained on these flours to extend the comparisons of the test values.

In Table I are tabulated the mean values of duplicate tests by each of the above methods. The precision of each method is indicated by expressing the average difference between duplicates as a percent of the range of values differentiating the flours. The degree of precision is nearly the same for all methods except the 3–2 hour pressuremeter values, which gave relatively low figures for differentiating values. Flour differentiation by the 2-hour pressuremeter method and the diastatic activity method was of the same order while the low differentiation established by the 3–2 hour method may be compensated for by the meaning of these values. The exact critical point in the rate of gas production was not determined on all flours, but close observation of the rate of gas production on a few high gas-producing flours indicated that the critical point had been reached before the 2-hour reading was made, and

[1] Subcommittee report, 1936–37 A. A. C. C. Committee on Methods of Analysis.
[2] Yeast activator supplied by R. M. Sandstedt.

TABLE I

A Comparison of Long and Short Time Pressuremeter Values and Diastatic Activity Value on 40 Samples of Commercial Flour (All Results Average of Duplicate Tests)

Sample number	Pressuremeter values				
	a	*b*	*c*	*d*	*e*
	6 hour	2 hour	3 hour	3–2 hour	Maltose per 10 g. flour
	3% yeast	5% yeast and 5% activator			
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mg.*
S–33	226	205	220	15	129
S–38	270	240	261	21	159
S–41	281	283	299	16	210
K–8	284	274	293	19	218
S–26	330	288	315	27	192
S–20	330	315	340	25	230
S–40	332	279	306	27	211
S–32	354	315	336	21	243
S–35	357	290	332	42	193
K–2	364	310	343	33	157
S–31	365	329	358	29	243
K–7	379	327	362	35	200
S–37	382	332	352	20	243
K–1	392	323	360	37	203
S–16	396	327	363	36	200
S–15	420	350	386	36	264
K–3	422	345	391	46	219
S–12	440	340	392	52	210
S–44	444	354	402	48	240
S–21	487	365	424	59	248
K–5	494	378	434	56	276
S–26	498	370	428	58	275
S–36	498	395	444	49	282
S–29	502	391	455	64	279
S–23	504	380	438	58	271
S–25	504	389	453	64	281
K–6	506	390	451	61	280
K–9	509	388	449	61	323
K–4	515	386	446	60	280
S–19	521	407	468	61	321
S–42	529	429	492	63	341
S–17	537	402	464	62	287
S–39	548	421	492	71	314
S–24	553	424	498	74	308
S–13	556	427	500	73	315
S–18	571	434	505	71	323
S–43	578	460	541	81	347
S–30	584	443	524	81	373
S–34	591	438	511	73	348
S–11	594	461	546	85	388
Mean	448.6	360.1	409.3	49.75	260.6
Mean difference between duplicates	3.30	3.2	3.4	2.25	3.27
Range of values	368	256	326	70	259
Duplicate differences as % of range	.9	1.2	1.0	3.2	1.3

$R_{ab} + .983 \pm .004$ $R_{ac} + .988 \pm .004$ $R_{ad} + .967 \pm .007$

$R_{ed} + .865 \pm .027$ $R_{ae} + .902 \pm .020$

the period from 2 hours to 3 hours was an index of the ability of the flour to sustain gas production after the readily available food was used up.

The correlation values between all gas production figures were sufficiently close to unity to indicate that the long- and short-time pressuremeter methods are measuring the same characteristics in flour. The diastatic activity values do not definitely place the flours in the order of their gas-producing ability as indicated by the correlation coefficients of $+ .902 \pm .020$ and $+ .865 \pm .027$. Some of the samples showing inconsistencies were tested for sucrose content and this factor accounted for the greater part of the variation, although other factors apparently entered into the difference in these test results. No further attempts were made in this study to account for these inconsistencies.

Summary

A comparison was made of the long and short gassing power methods and diastatic activity tests on forty commercial flours. The figures obtained were:

	Average value	Range of differentiating values	Average difference between duplicate tests	Duplicate difference as % of range
a. 6-hour pressuremeter values mm.	448.6	368	3.30	.9
b. 2-hour pressuremeter values mm.	360.1	256	3.20	1.2
c. 3-hour pressuremeter values mm.	409.3	326	3.40	1.0
d. 3–2 hour pressuremeter values mm.	49.75	70	2.25	3.2
e. Diastatic activity mg. maltose per 10 g. flour	260.6	259	3.27	1.3

Correlation coefficients

$R_{ab} + .983 \pm .004$ $R_{ac} + .988 \pm .004$ $R_{ad} + .967 \pm .007$

$R_{ae} + .902 \pm .020$ $R_{de} + .865 \pm .027$

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AN IMPROVED WIDE-RANGE VOLUME-MEASURING APPARATUS FOR SMALL LOAVES [1]

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(Read at the Annual Meeting, May 1937)

A volume-measuring device for small loaves was described by Geddes and Binnington (1928); this apparatus was later modified by Malloch and Cook (1930) and in this form is recommended by the A. A. C. C. (1935) to be used in conjunction with the Standard Baking Test. In either its original or modified form, it has been employed by the Canadian cereal laboratories co-operating with the Associate Committee on Grain Research of the National Research Council of Canada. In recent years the range and capacity of the apparatus were found inadequate and it was therefore decided to redesign it completely and investigate the whole question of loaf volume measurement with a view to ascertaining whether or not the present system could be improved.

Preliminary Considerations

Fundamentally, volumes of solids may be determined by three methods: (1) direct measurement and calculation, (2) density measurements, and (3) measurements of the displaced volume of either a gas, liquid or finely divided solid. The latter two methods are of course directly related but from a practical standpoint can be classed separately. As applied to the present problem, only displacement methods using either a liquid or a solid appear to possess any practical value, and the first of these is applicable only to research problems due to the necessity of water-proofing the loaf by impregnation with wax or some similar process. Under these circumstances, apparatus employing the displacement of a free-flowing solid offers the only feasible method of measuring loaf volume. The choice of a suitable solid is limited by the particular requirements involved, which may be summarized as:

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[2] Research Assistant, Associate Committee on Grain Research.

[3] Chemist in Charge, Grain Research Laboratory, Board of Grain Commissioners, Winnipeg, Manitoba.

[4] The authors are indebted to J. G. Malloch, A. G. O. Whiteside, R. K. Larmour and A. G. McCalla for their valuable suggestions in connection with the design of this apparatus.

Free-flowing.
Minimum of adherence to the loaf and apparatus.
Uniformity of size and shape of particles, *i.e.* uniform packing characteristics.
Low density.
Unaffected by moisture.
Mechanical strength.
Minimum of abrasive action.

The only materials that appear to conform to the majority of the above requirements are various types of seeds, although small glass beads or metal shot would undoubtedly be superior were it not for their high density exerting a compressive effect upon the loaf. It is possible that some form of low density plastic might be developed for this purpose but nothing of this kind appears to be available at present. Of the various seeds proposed for this purpose, rape and flaxseed have been most widely used. Whitcomb (1925) carried out measurements of commercial-sized loaves in different types of apparatus employing rape, flaxseed, sweet clover, millet, vetch, wheat and peas and his data indicate that rape seed is probably the most suitable for small loaves.

The various mechanical devices used in conjunction with seed are all based essentially upon measurement of the volume of seed displaced by the loaf, although Whitcomb (1925) mentions a method employed by a German investigator in which the displaced seed is weighed and its volume computed. In its simplest form the seed displacement method is applied with the aid of a suitable box and large measuring cylinders. Apart from the time involved in making a test, this method is subject to serious error due to the fact that seed does not pack uniformly unless fed from a special distributing device. This "packing error" enters not only into the actual application of seed to the loaf but also to the measurement of both the original and residual seed volumes. An instrument in which seed is displaced upwards and around the loaf by means of a calibrated piston or similar device would eliminate this packing factor; experiments showed, however, that rape seed or flaxseed would not flow freely under such conditions and exerted a compressive effect upon the loaf. As apparatus of the hour-glass type helps to minimize the packing error, efforts were directed toward improving upon the earlier designs based upon this principle.

The normal working range of the original machine was 450 c.c. to 650 c.c.; this could be extended to 850 c.c. by allowing the seed to rise above the central diaphragm, or alternatively, a known volume of seed could be removed or a different size of standard loaf substituted. None of these alternatives is very satisfactory from a practical stand-

point and in any event the capacity is limited by the size of the measuring hopper which will not conveniently accommodate loaves in excess of 900 c.c. volume. With the instrument described by Malloch and Cook (1930) the normal working range was 550 c.c. to 950 c.c. and the measuring hopper was somewhat larger, but even with this improved design the apparatus was not capable of dealing with loaves of 1,000 c.c. to 1,300 c.c. volume, such as have been encountered in recent high protein years and by the use of new baking formulas. Obviously, the first step to be taken was to increase the size of the hoppers considerably but this alone does not solve the problem, because, unless the bore or length of the measuring tubes is materially increased, the normal working range remains at 400 c.c. Increased bore naturally means decreased accuracy and this is not desirable; on the other hand any worthwhile increase in length would render the apparatus cumbersome and fragile. The use of several standard loaves would accomplish the desired end but would be decidedly inconvenient, necessitating the addition or removal of seed and resetting of the zero point whenever loaves of a wide volume range were encountered.

Principles of New Design

In the new design these difficulties have been overcome and a continuous working range of 1,000 c.c. obtained by the following method:

One hopper is used as a seed receptacle only, the other serving for both calibration and measurement. Four identical lids are provided for this so-called loaf hopper, to one of which is permanently attached a metal standard loaf of exactly 900 c.c. volume; two of the remaining lids are fitted with solid rectangular metal "filler" blocks of 600 c.c. and 300 c.c. volume, respectively. The instrument is first standardized by fitting the "standard loaf lid" to the loaf hopper and adding seed to the zero mark on the graduated tube. The apparatus is then inverted, the seed transferred to the "storage" hopper, the "standard-loaf lid" removed and replaced by a measuring lid to which is attached the loaf whose volume is to be measured, the apparatus reinverted and a reading taken of the seed height in the tube. If the plain lid is used, loaf volume is obtained by adding 900 c.c. to the tube reading; with the 300 c.c. "filler-block" lid, by adding 600 c.c.; and with the 600 c.c. filler lid, by adding 300 c.c. It will thus be seen that the range of the instrument is as follows:

Plain lid	900 c.c. to 1,300 c.c.
300 c.c. "filler" lid	600 c.c. to 1,000 c.c.
600 c.c. "filler" lid	300 c.c. to 700 c.c.

Each lid has therefore a 100 c.c. overlap at each end of its range, making a critical matching of lid to loaf unnecessary, except in the case of occasional "borderline" samples. This method obviates the necessity of frequent interchange of standard loaves and resetting of the zero, thus enabling the baker to measure loaves to a five-minute schedule without assistance when baking up to 36 loaves a day.

Constructional Details

The general constructional details are illustrated in Figures 1 and 2 and the completed instrument in Figure 3. The seed-distributing

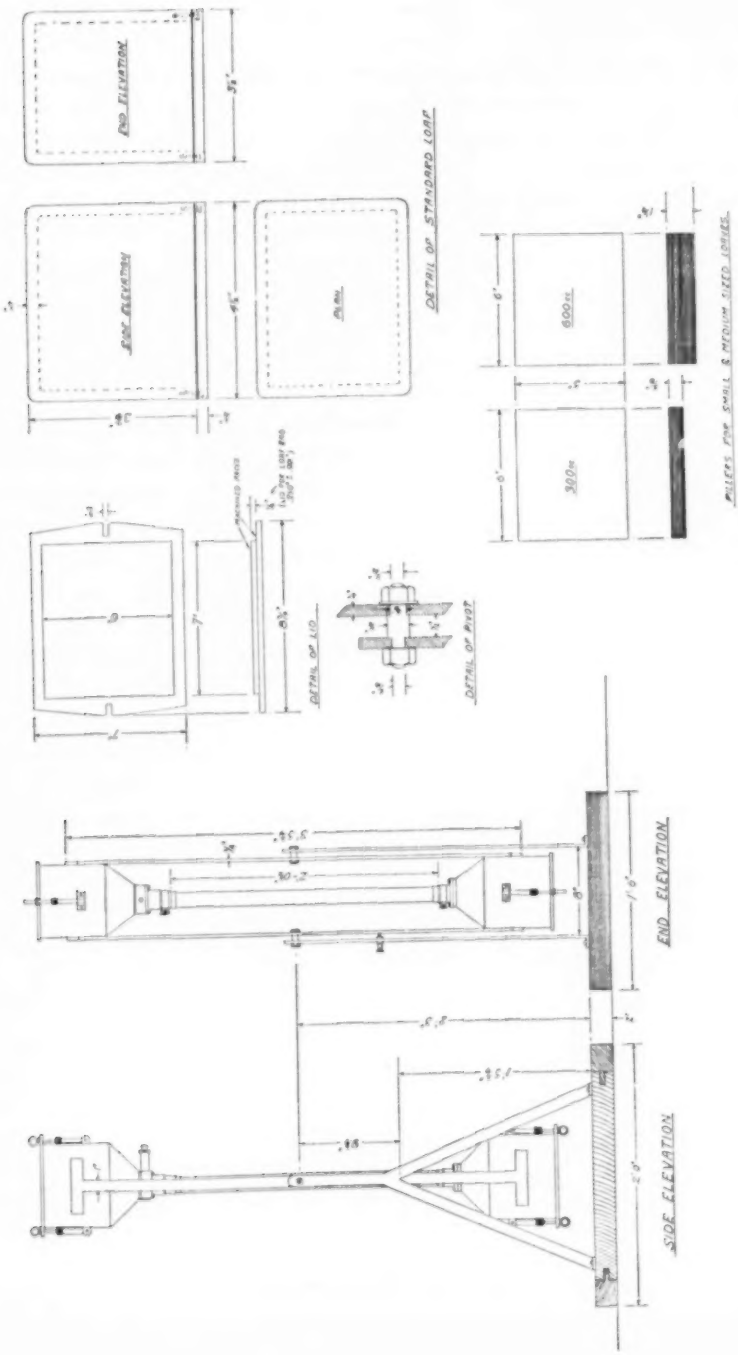

Figure 1. General constructional details.

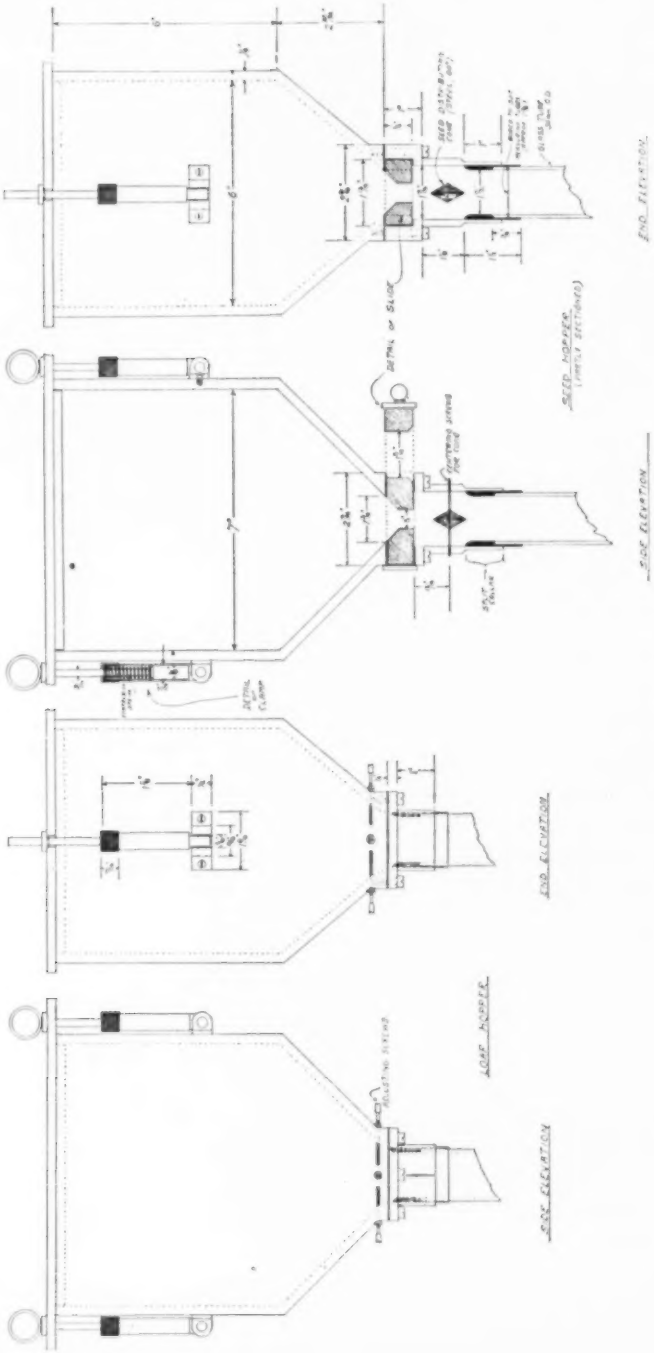

Figure 2. Details of hoppers.

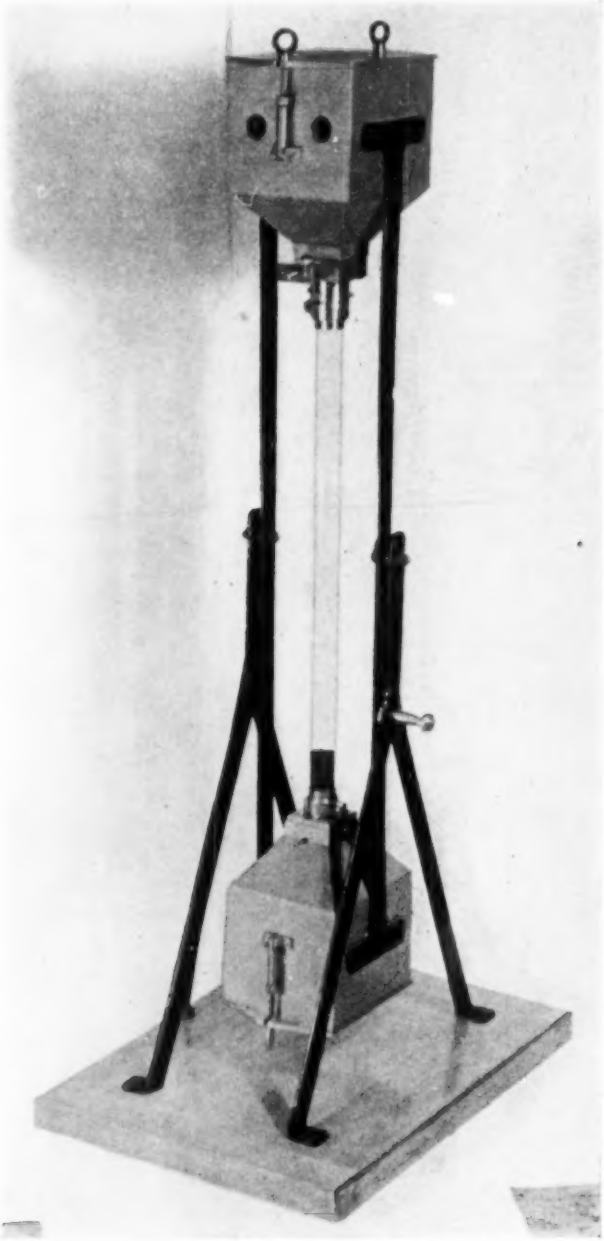

Figure 3. Loaf measuring device.

device described by Malloch and Cook (1930) has been employed with the slight modification of a double 60° hardened steel cone instead of the steel ball employed by these authors. This device provides a very uniform flow of seed and enables the full length of the measuring tube to be utilized. The general specifications are as follows:

Hoppers—Smooth, aluminum alloy castings internally free from roughness, ledges and sharp corners, and machined top and bottom.

Lids—Aluminum alloy, machined both sides, rebate on loaf lids to be 0.250 inch ± 0.001 inch. Rebate on seed hopper lid ¼-inch (not critical). Minimum clearance between rebate and side walls of hopper. "Loaf-lids" to be fitted to hopper with square corners, "seed-lid" with round corners, in order to prevent interchangeability.

Filler blocks—Solid aluminum alloy, machined all over and adjusted to 600 c.c. and 300 c.c. volume ± 0.5 c.c. Volumes to be determined by weighing in air and water.

Standard loaf—Aluminum alloy, cast hollow, machined on bottom and closed watertight with machined aluminum plate. Final volume of 900 c.c. ± 0.5 c.c. to be obtained by machining and measurement as above.

Tube fittings—Cast brass, machined all over, caps for tubes to be fitted individually.

Sliding block—Aluminum alloy, machined all over, seed aperture exactly ⅝-inch in diameter. End plates of brass. A flat spring or similar device to be fitted in order to provide adequate friction and hold the slide in place.

Measuring tube—Of Pyrex glass, 35 mm. outside diameter, 25 inches long, graduated at 10 c.c. intervals, graduated portion to be centrally spaced. All lines to completely encircle the tube and each line numbered with as large figures as possible. Numbering to read *upwards*, *i.e.*, zero at the bottom. Maximum allowable variation shall not exceed 1.0 c.c. on the total capacity.

Loaf attachment device—The three measuring lids shall be fitted with hardened steel spikes, as indicated, for impaling the loaf and in addition with suitable steel pegs or hooks whereby a rubber band may be stretched over the loaf to hold it in position. In the case of the 600 c.c. and 300 c.c. lids, these shall be short pins driven into the sides of the filler block. For the plain lid they shall be "L" shaped hooks fitted to the under surface of the lid.

General—The machine shall be so mounted as to pivot freely and be provided with a suitable spring-operated stop pin functioning at both ends of the travel.

Five machines were constructed according to the above specifications, the final machining and adjustment of the filler-blocks and standard loaves being made in the laboratory. The instruments were then assembled for test. As originally designed, the seed opening in the sliding block was only ½ inch in diameter and under these conditions 4¾ minutes were required for complete transfer of seed. This rate was entirely too slow and the opening was enlarged by 1/64-inch increments until the satisfactory rate of 1¾ minutes was obtained with a 5/8-inch opening. During these tests it was noted that increasing the size of aperture and rate of feed caused the seed to pack more loosely and a volume increase of 130 c.c. was found between the two extremes. This clearly indicates the importance of an accurately controlled rate and manner of feed. At the final value, however (5/8-inch and 1¾ minutes), the seed still packed so uniformly that even violent jarring of the apparatus caused no change in level.

Adjustment and Calibration

Following assembly of the machines and adjustment of the feed rate, the instruments were checked with four dummy loaves designated A, B, C and D, modelled from wood and waterproofed with shellac. Their true volumes were determined by weighing in air and water and loaves A, B and C measured on the "600 c.c." lid and loaves C and D on the "300 c.c." lid. For purposes of comparison, they were also measured by the conventional "box" method, together with one of the 900 c.c. metal standards. The results for a single machine are given in Table I.

TABLE I

TRUE AND APPARENT VOLUMES OF WOODEN DUMMY LOAVES

Loaf	Lid	True volume	Apparent volume, Machine No. 1	Volume difference true, Machine No. 1	Apparent volume, Box method	Volume difference true, Box method
		C.c.	*C.c.*	*C.c.*	*C.c.*	*C.c.*
A	600 c.c.	446	410	−36	403	−43
B	600 c.c.	545	500	−45	501	−44
C	600 c.c.	635	583	−52	574	−61
C	300 c.c.	635	588 (estimated)	−47		
D	300 c.c.	816	758	−58	753	−63
900 c.c. Standard					843	−57

It will be noted that considerable discrepancies existed between the true and measured volumes, the instrument yielding low results in all cases, and furthermore that these differences were not consistent. These results were very disturbing and a careful check was accordingly made of all standardizations; in addition a critical analysis was made of possible sources of error from which it was finally concluded that the discrepancies were due to differences in seed packing caused by variations in both the size and shape of the loaf being measured. At first sight it would appear surprising that such effects had not been noted in early models of this type of machine. It is probable, however, that any such effect was minimized by the relatively small range and seed capacity of these earlier instruments. It was thought that the manner in which the seed struck the top of the loaf might be a controlling factor and one of the instruments was modified by the introduction of a blunt cone (35°) set immediately within the entrance to the measuring hopper. By this means the seed was thrown to the side and gradually filled up around the loaf instead of striking it directly. The use of this device increased the apparent volumes by from 46 c.c. to 93 c.c., thus making them from 10 to 35 c.c. "greater" than the actual volumes. Removing the cone but leaving the four

set screws in place with their points in contact gave apparent volumes differing from the true values by only − 2 c.c. to + 13 c.c. A series of tests was then made to determine the most satisfactory setting for these screws; this was found to correspond to a circular aperture of 16 mm. diameter, at which setting they were then locked firmly in place.

Although the introduction of these adjusting screws greatly reduced the error, discrepancies still existed when loaves of a considerable range in volume were measured. It therefore became necessary to construct calibration curves for each machine. A series of standards was essential for this purpose and in view of the apparently marked effect of size and shape of loaf upon the results obtained, it seemed highly desirable that such standards should closely approximate actual loaf shapes. This requirement precluded the use of water-filled rubber balloons as described by Harrel (1928) and employed by Heald (1929). Wooden dummies are tedious to construct, particularly if accurately modelled to prototype and aluminum models as described by Bailey (1930) require a pattern from which to be cast. As time was an important factor, models were prepared by baking an extensive series of loaves ranging in volume from approximately 300 c.c. to 1,500 c.c.; these were then thoroughly air dried and 12 loaves approximating the desired standards selected. Each loaf was trimmed to reasonably symmetrical shape with the aid of a rotating steel brush and a rasp, thoroughly impregnated with hot paraffin and built up to the desired shape and volume by modelling with dental wax. The final true volumes were obtained by weighing in air and water. The final true volumes to the nearest cubic centimeter were 315, 416, 506, 620, 662, 754, 867, 909, 956, 1045, 1124 and 1234 c.c., so that five to six loaves were available for checking each lid and filler block combination. With the aid of these wax models a correction chart was constructed for each machine and it is intended to use these dummy loaves as patterns for the production of permanent metal models.

Operation

In use, the loaf is impaled upon the spikes which are staggered in such a manner that the loaf may be easily cut for judging without interference from the indentations. A disc of thin dental rubber 2 inches in diameter is placed upon the top of the loaf and a rubber band of suitable tension employed to hold it firmly in position. This method of attachment is rapid and convenient to use and has no tendency to alter the loaf volume as is the case with spring clips applied to the ends of the loaf. The purpose of the dental rubber is to avoid the abrasive effect of the falling seed upon thin-crusted or shell-top

loaves which, on account of the height of fall and quantity of seed rapidly cuts a hole in the top of such loaves. The zero point is checked with the standard loaf at frequent intervals (every 3 to 5 readings) and any deficiency in seed restored.

In order to secure an index of the precision of measurement, three of the wax dummy loaves were selected and 25 replicate readings made with each loaf on each of two successive days. The results of the uncorrected readings summarized in Table II show highly satisfactory replicability over the entire range of the apparatus:

TABLE II

PRECISION OF MEASUREMENT

Loaf model number Lid range in c.c.	3 300 to 700		6 600 to 1,000		10 900 to 1,300	
	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
Mean loaf volume, c.c.	524	521	759	760	1049	1049
Minimum loaf volume, c.c.	519	517	755	757	1046	1045
Maximum loaf volume, c.c.	528	524	762	762	1052	1053
Standard deviation of loaf volume in c.c.	2.60	1.94	1.74	1.32	2.17	2.37
Coefficient variation of loaf volume, %	0.50	0.37	0.23	0.17	0.21	0.23
Standard error of single determination (both days) c.c.	2.60		1.54		2.25	

Effect of Shape and Surface Finish

Since it was found that both the size and shape of the object to be measured affected the results, it seemed desirable to attempt to secure an indication of the effect of loaf shape alone. Accordingly, a plaster mold was made from one of the wax models and a number of replicas cast in plaster of Paris. After thorough drying, three of these replicas were built up with the same weight of dental wax to represent (*a*) a normal, bold, symmetrical loaf, (*b*) a bold loaf with a "lop-sided" crown, and (*c*) a flat-topped, reasonably symmetrical loaf such as would be obtained from excessively runny doughs made from severely sprouted wheat flour. The true volumes of these loaves (ascertained by weighing in air and water) were (*a*) 888, (*b*) 893, and (*c*) 908 c.c., and the mean of ten uncorrected readings thereon 897, 911 and 948 c.c., respectively. Thus, the discrepancy between true and observed volume due to shape alone is 9, 18 and 40 c.c. for the "symmetrical," "lop-sided" and "flat-topped" loaves, respectively. This indicates that seed packing is definitely affected by loaf shape and that appreciable errors may occur in measuring abnormally shaped loaves.

In view of the desirability of constructing a set of permanent metal standards for calibration purposes, some experiments were conducted to determine whether the surface finish appreciably influenced the packing of the seed. To this end three of the plaster replicas previously referred to were water-proofed with several coats of lacquer. Thin aluminum foil was cemented to one; a second was provided with an exceedingly rough surface by applying a coat of nitro-cellulose cement and sprinkling with rough sand followed by a coat of lacquer to ensure adequate binding; the third was simply covered with a thin film of dental wax. The true volumes were then determined and ten replicate readings made with the measuring device. The corrected volumes differed from the true by -7, $+7$ and $+2$ c.c. for the metal, rough and wax surfaces, respectively. While these differences are relatively slight, they indicate that a smooth, highly polished surface promotes closer packing of the seed as compared with a rough surface.

The use of plaster or metal models is open to the criticism that they are less resilient than bread and therefore the seed will rebound to a greater extent from their surfaces with a consequent effect upon the packing. That the use of the rubber disc upon which the seed strikes greatly minimizes this condition has been shown experimentally. These experiments suggest that in constructing permanent metal loaf models, the surface should preferably be not highly polished.

Discussion

The experiences encountered in the construction and calibration of these loaf-measuring devices indicate that such apparatus may be an important source of error within and between laboratories; for instance, the slightest variation in the position of the small set screws situated in the throat of the loaf-measuring hopper caused appreciable differences in apparent loaf volume and this emphasizes the sensitivity to slight variations in construction of any device based on the principle of seed displacement. That the size, shape and surface of the object to be measured introduced differences in the manner in which the seed packs has been definitely shown. When the volume of the system has been established by means of a rectangular shaped metal standard, a loaf-shaped object of the same volume will not give the same reading. However, in view of the difficulties involved in constructing loaf-shaped standards of metal, together with the fact that a calibration curve is essential in any event, the rectangular shaped standard as described is considered to be quite satisfactory for the purpose.

In view of the importance placed upon loaf volume and of present efforts of the Committee on Standardization of Laboratory Baking to

eliminate avoidable sources of variation, our experiences emphasize the need for a standard official apparatus, together with the provision of facilities for frequent recalibration.

Summary

The constructional details and specifications for a standardized loaf-measuring device based on the hour-glass principle employing rape seed and with a range of 300 to 1,300 c.c. are presented.

The apparent volumes obtained with such a device are influenced by the rate of seed flow and the manner in which the seed strikes the loaf, as well as by the size, shape, and surface finish of the object to be measured. It is consequently necessary to calibrate the apparatus with a series of loaf-shaped objects of known volume.

Loaf-volume apparatus may be an important source of error within and between laboratories and there is need for a standard official apparatus together with the provision of facilities for frequent recalibration.

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TWO FURTHER SIMPLE OBJECTIVE TESTS FOR JUDGING CAKE QUALITY

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In addition to the excellent objective tests already reported in the literature, especially by Platt and Kratz,[1] the author has found two very simple additional objective tests helpful in evaluating cake quality. By the first test a measure can be obtained of the average relative size of the pores or grain of the cake. By the second, the ability of the cake to take up water is determined as one possible index to the eating characteristics of the cake. These tests will be described in detail, and some typical results given to show what may be expected.

Sand Retention Test for Grain of Cake

Photography gives a graphic record of the fineness or coarseness of the cake, but does not give results capable of quantitative comparison. For a quantitative test, some highly uniform substance, composed of small particles, if poured onto sections of the cake and allowed to penetrate the pores in a uniform manner and then weighed, should give a measure of the average size of the grain of the cake. Sand was selected for the substance to be used, because of its cheapness, its accessibility, its density, and its ease of sifting to uniform particle size. It was prepared for use by sifting through a 30-mesh sieve, and then using the portion retained by a 40-mesh sieve.

Four samples of each cake were prepared for the test by cutting horizontal sections one inch thick, free from top and bottom crust. The surface tested was the bottom of the slab, for the texture of the cake near the bottom is much more uniform than at the top. Rounds, two inches in diameter, were cut from these slabs with an ordinary biscuit cutter. These four pieces were then weighed individually to 0.01 g., as much care as possible being taken to prevent drying. All the pieces to be tested were covered very generously with the sifted sand, until no more would remain on them, and then each piece in turn was placed on a 40° incline and rotated once to permit as much sand to fall off as was not retained in the pores. The pieces were then

[1] Platt, Washington, and Kratz, Philip D. Measuring and recording some characteristics of test sponge cakes. Cereal Chem. 10: 73–90 (1933).

weighed again, and the difference in weight recorded as a measure of the coarseness of the grain.

There are a number of factors that make for inaccuracy in this test. Listed briefly, they are: (1) Variation in texture of the cake from place to place and batch to batch; (2) variation in cutting of samples, *i.e.*, nearer or farther from bottom crust, surfaces not parallel, etc.; (3) variation in manner of adding sand; and (4) loss of weight by evaporation of moisture during test.

In spite of these factors, fairly consistent results can be obtained. Table I records some typical results on one cake, while Table II records the results that have been obtained on a series of yellow, white, and devil's food cakes made with lard and with a hydrogenated vegetable oil shortening.

TABLE I

ORIGINAL DATA ON SAND-RETENTION TEST FOR GRAIN. DEVIL'S FOOD CAKE MADE WITH LARD, FIFTH BAKING

Sample number	1	2	3	4
	G.	*G.*	*G.*	*G.*
Weight of cake + sand	18.71	19.75	19.22	20.61
Weight of cake	16.67	17.63	17.09	18.74
Weight of sand	2.04	2.12	2.13	1.87

TABLE II

SAND RETENTION OF YELLOW, WHITE, AND DEVIL'S FOOD CAKES MADE WITH LARD AND WITH HYDROGENATED VEGETABLE OIL SHORTENING

(Grams sand retained)

Baking number	Yellow [1]		White		Devil's Food	
	Lard	Hyd. V.O.[2]	Lard	Hyd. V.O.[2]	Lard	Hyd. V.O.[2]
1	2.32	1.84	1.90	1.68	2.27	1.74
2	2.30	2.30	1.51	1.43	1.47	1.57
3	—	—	1.75	1.65	1.75	2.17
4	—	—	1.72	1.70	2.06	1.96
5	—	—	1.72	1.59	2.04	1.94
6	—	—	1.70	1.44	1.75	1.82
Average	2.31	2.07	1.72	1.58	1.89	1.87

[1] These data reprinted from "How to Use Lard in Making Bakers' Cakes," Baker's Helper, Chicago, May 15, 1937.
[2] Hydrogenated vegetable oil shortening.

The data presented in Table I show that at least a fair degree of agreement can be expected from four samples of the same cake.

The figures in Table II are indicative of the reliability of the test. In each pair of cakes, one made with lard and the other with the

hydrogenated shortening, the one made with lard had the more open grain, both according to inspection and according to the sand retention test. In the case of the three types of cakes, yellow, white, and devil's food, the difference between the cakes made with the two shortenings was least in the devil's food type of cake, both by inspection and by test.

Water Absorbing Ability, or "Wetability"

At least part of the eating character of cake is due to the ability of the cake to become moistened with saliva in the first few seconds of chewing. A cake that resists moistening will feel dry and unpleasant in the mouth, while one that moistens quickly is far more palatable. This quality or ability to absorb water is a simple measure also of the freshness of a cake, for the ability to take up water decreases as the cake becomes stale.

The test for this property is performed as follows: Four rounds of each cake being compared are cut exactly as for the sand-retention test, and the surface nearest the lower crust of the cake used. Each piece is weighed to 0.05 g. and placed into a Petri dish cover [2] containing 30 c.c. of water at room temperature. The cake is allowed to remain in the water exactly five seconds, removed, inverted quickly to prevent loss of water, and weighed again immediately. The difference in weight represents the water absorbing ability or the "wetability" of the cake.

Some typical results are given in Table III to show the agreement that may be expected in this test.

TABLE III

ORIGINAL DATA ON WATER-ABSORBING ABILITY. DEVIL'S FOOD CAKE MADE WITH LARD, SIXTH BAKING, THREE DAYS OLD

Sample number	1	2	3	4
	G.	*G.*	*G.*	*G.*
Weight of cake + water	28.50	25.45	27.00	27.75
Weight of cake	17.70	15.25	16.90	17.45
Weight of water	10.80	10.20	10.10	10.30

In Table IV results are given for three types of cakes, yellow, white, and devil's food, each made with lard and with a hydrogenated vegetable oil shortening.

These results show that cakes vary in their ability to take up water, and that as they become stale they lose that ability, some more rapidly than others. But since it is inherent in fresh cake, greater "wet-

[2] Diameter 9.7 cm. Depth of water approximately 5 mm.

TABLE IV

WATER-ABSORBING ABILITY OF YELLOW, WHITE, AND DEVIL'S FOOD CAKES MADE WITH LARD AND WITH HYDROGENATED VEGETABLE OIL SHORTENING

(Grams water absorbed)

Age in days	Yellow		White		Devil's Food	
	Lard	Hyd. V.O.[1]	Lard	Hyd. V.O.[1]	Lard	Hyd. V.O.[1]
0	13.59	13.65	14.58	10.37	12.72	10.32
1	12.61	12.71	12.95	7.07	11.68	8.25
2	11.73	11.98	12.20	6.25	10.81	7.27
3	11.53	11.82	11.71	5.26	9.82	6.30
4	10.98	11.80	11.69	4.72	9.48	5.60
5	—	—	11.01	4.26	9.17	5.21
7	—	—	10.10	3.51	8.51	4.32
Number of bakings	2	2	6	6	6	6

[1] Hydrogenated vegetable oil shortening.

ability" can be considered a desirable quality. While it is, of course, nothing more than an extremely simple index to eating quality, not taking into account flavor, aroma, velvetiness, color, tenderness, elasticity, general appearance, or any of the other important factors comprising eating quality, nevertheless a series of consumer acceptance tests has borne out its worth as an index. In tasting tests on the yellow cakes, over 1,000 individuals were practically equally divided as to preference for the two kinds. The "wetability" test shows the two yellow cakes very nearly equal in that quality. Of over 500 who tasted the white cakes, the cake made with lard was preferred by a ratio of 5 to 4. Again the preferred cake had the greater water-absorbing ability. The same relationship held true with the devil's food cakes. The lard cake was preferred in the ratio of 13 to 4 by 500 individuals, and as Table IV shows, its "wetability" was considerably greater than that of the cake with which it was compared.

Apparently, then, this ability of cakes to take up water rapidly is in some way correlated with a desirable eating quality. No other explanation is offered for this correlation except the observation that those cakes that have a poor "wetability" are the ones that feel dry in the mouth on eating.

A COMPARISON BETWEEN THE 100 AND 25 GRAM BAKING METHODS

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In evaluating new types of wheat produced by plant breeders it is of primary importance that a suitable and reliable test of quality be available which can be applied to a relatively small quantity of the wheat, thereby saving much valuable time to the breeder by ruling out as early as possible varieties which are quite unsuitable for the production of bread. The usual experimental milling and baking technique requires approximately 2000 g. of grain to furnish a complete picture of the milling and baking possibilities of the wheat. Several hundred grams of flour are necessary to obtain authentic information relative to the baking quality of the sample under examination in the instance of the customary baking procedure which calls for 100 g. of flour for each loaf. It is quite impossible to test out by this method small samples of flour which are often sent by mail for determination of baking quality. For these reasons other tests of quality have been persistently sought.

The wheat-meal fermentation time test was developed by Cutler and Worzella (1931, 1933) to solve this problem, while Pelshenke (1933) advocated a similar method for testing strength in native and imported German wheat. Bayfield (1935) concluded that the fermentation time test could only roughly group wheat on the basis of strength. These groups could be quite satisfactorily differentiated by the protein test and the time test could not be substituted for experimental milling and baking. Later Bayfield (1936) conducted an extensive investigation of the fermentation time test by comparing it with other well known criteria of baking quality and found that the baking procedure was the best test for flour strength. Bayfield and Shiple (1937) postulated that the Kjeldahl nitrogen determination is the most accurate and rigid single method of testing strength in soft winter wheat flours, but it does not take into account variations in protein quality. These workers found loaf volume and viscosity to be more valuable and accurate than the wheat-meal time test.

Geddes and Frisell (1935) described an experimental mill for producing flour from quantities of wheat as small as 100 g. Geddes

and Aitken (1935) published a description of an experimental baking technique designed to use only 25 g. of flour, and which could be satisfactorily employed with micro mill flour. Geddes and Sibbitt (1933) reported the findings of a preliminary study on this procedure and thought that it would differentiate satisfactorily between flours of different baking strength. Geddes and Aitken found the values obtained by the 25-gram technique to be highly correlated with the 100-gram loaf volume yielded by the same series of flour. This baking procedure appears to combine benefits obtained by the use of a relatively small sample with the possibility of obtaining information as to baking quality similar to that yielded by the Standard Baking Procedure, or its modification.

Material and Methods

In view of the advantages cited which accrue to the use of the micro baking method, it was decided to conduct a preliminary study of the relationship existing between the loaves produced by the new method and those obtained by using the 100-gram procedure using flour produced from North Dakota wheat. Accordingly, 76 samples of 70% patent flour experimentally milled from North Dakota hard red spring wheat were baked by the two methods. The doughs were mixed in the Hobart-Swanson for 2 minutes, 50 g. of flour being used in the instance of the small loaf and the doughs subsequently aliquoted before placing in the fermentation bowl. The baking tins employed were modeled after the ones used by Geddes and Aitken (*loc. cit.*) and were of the following dimensions: top 7.1 × 4.4 cm.; bottom 5.9 × 3.3 cm.; height 3.2 cm., similar in shape to the standard low-form tin. The loaves were measured in an apparatus of a rape seed displacement type. In other respects the baking formula followed was the Standard A. A. C. C. Procedure with 5% sucrose. The large loaves were baked in a similar manner (Standard Procedure plus 5% sucrose).

As Geddes has pointed out, the surface of the cut loaves from 25 g. of dough is too small to score satisfactorily for crumb color and texture, accordingly the only loaf characteristic considered here is loaf volume. This attribute is also subject to quantitative measurement.

Discussion

The loaf volumes obtained by the baking procedures are shown in Table I. The data are arranged in order of increasing wheat protein content, as this variable is commonly used in rating wheat strength. The 100-gram Standard Method did not give very large loaves even with the higher protein wheats of this series. Neither of the two baking methods used would appear to differentiate sharply among the

TABLE I

COMPARATIVE LOAF VOLUMES OBTAINED BY THREE BAKING METHODS

Sample number	Crude wheat protein (N×5.7)	Loaf volume	
		100 g. method.	25 g. method
		Standard basic	Standard basic
	%	*C.c.*	*C.c.*
1	13.8	413	90
2	14.5	469	108
3	14.6	402	95
4	14.9	417	96
5	15.1	403	96
6	15.4	460	126
7	15.4	470	114
8	15.4	453	101
9	15.6	442	98
10	15.7	386	107
11	15.8	465	109
12	15.9	362	110
13	16.1	472	113
14	16.3	319	85
15	16.3	386	91
16	16.3	397	98
17	16.4	458	97
18	16.4	319	79
19	16.4	487	106
20	16.4	455	96
21	16.4	494	123
22	16.5	442	101
23	16.5	374	87
24	16.5	392	94
25	16.5	400	108
26	16.5	515	125
27	16.6	376	96
28	16.6	376	95
29	16.6	417	105
30	16.7	433	97
31	16.8	470	110
32	16.8	497	108
33	16.8	500	114
34	16.8	391	91
35	16.8	487	134
36	16.8	533	133
37	16.9	524	110
38	16.9	504	118
39	16.9	475	101
40	16.9	356	89
41	17.0	467	117
42	17.0	478	117
43	17.1	406	104
44	17.1	545	130
45	17.1	454	101
46	17.1	597	136
47	17.1	342	92
48	17.2	534	123
49	17.2	457	97
50	17.2	585	112
51	17.2	471	132
52	17.2	480	115

TABLE I—*Continued*

Sample number	Crude wheat protein (N×5.7)	Loaf volume	
		100 g. method	25 g. method
		Standard basic	Standard basic
	%	*C.C.*	*C.c.*
53	17.3	569	133
54	17.4	563	137
55	17.4	564	117
56	17.4	560	135
57	17.4	558	134
58	17.5	542	120
59	17.5	543	119
60	17.5	551	130
61	17.5	577	111
62	17.5	538	121
63	17.5	554	131
64	17.8	574	108
65	17.8	567	120
66	17.8	563	120
67	17.8	590	130
68	18.0	532	127
69	18.0	582	118
70	18.1	515	117
71	18.1	567	122
72	18.2	507	106
73	18.3	610	123
74	18.5	616	132
75	18.6	575	147
76	19.5	475	96

wheats on a protein content basis. This is in agreement with a former paper (Harris, 1937), when no significant correlation between crude flour protein and loaf volume was found in the instance of 30 samples of 1936 North Dakota hard red spring wheat.

In Table II the statistical constants calculated from the baking data are shown. The Standard 100-gram Baking Procedure yielded the largest mean loaf volume and showed the greatest variability, while the 25-gram method had the least. The correlation coefficients show a significant relationship between wheat protein and loaf volume for the two methods.

While the relationship between the 100-gram and 25-gram loaves may not be of sufficient magnitude in the present instance to predict 100-gram loaf volume with great accuracy from a knowledge of the 25-gram loaf size, yet it is evident that undesirable and weak wheat varieties can, from the information made available by this procedure, be eliminated very much earlier than would be true otherwise, and much useless work thereby saved. Strong wheats, on the other hand, would be apparent also and their production speeded up with appreciable economy of time and effort.

TABLE II

TABLE OF STATISTICAL CONSTANTS

Mean Loaf Volumes, Standard Deviations, and Coefficients of Variability

	Means	Standard deviation	Coefficient of variability
Standard 100-gram procedure	481.6	74.88	15.53
Standard 25-gram procedure	111.6	15.07	13.50

Simple Correlation Coefficients

Variables correlated		r_{xy}	P[1]
x	y		
Crude wheat protein	Loaf volume standard 100-gram bake	+.5918	<.0000002
Crude wheat protein	Loaf volume standard 25-gram bake	+.4566	.0000008
Loaf volume standard 100-gram bake	Loaf volume standard 25-gram bake	+.8068	<.0000002

[1] P = the probability of the observed correlation coefficient arising from uncorrelated material through errors of random sampling.

Summary

A series of 76 experimentally milled North Dakota hard red spring wheat flours were baked by two procedures—the Standard 100-gram Method, using the basic ingredients of flour, water, sugar, salt and yeast, and a 25-gram procedure similar to the Standard Method described, except for quantity of flour used.

A significant correlation between loaf volume and wheat protein content was shown by the two baking methods. A relatively high positive correlation was found between the two Standard Methods. This relationship, while not sufficiently high to permit of accurately predicting 100-gram loaf volume, would prove useful in differentiating strong and weak wheat varieties, thereby justifying its use as a method for baking when sufficient material is not available for the Standard 100-gram Procedure.

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BOOK REVIEW

Wheat and Flour Quality. By C. O. Swanson. Published by Burgess Publishing Co., Minneapolis, Minn. 227 pages mimeographed. 1938. Price $3.00.

The twenty-six chapters of this book were based upon the lectures delivered by Prof. Swanson to his classes at the Kansas State College during recent years. A variety of topics is covered, including definition and measurements of wheat and flour quality, constituents of wheat, types of wheat and the influence of soil and climate on quality, storage of wheat and flour, chemical technology of milling, and related subjects. Sections dealing with the statistics of wheat production and the position of bread in the diet are also included. Incidentally, the preparation of this manuscript afforded Prof. Swanson an opportunity to bring together in one book the material which had heretofore been scattered through several trade journals, and hence none too available to the average student of this subject.

The book is replete with useful facts. Sometimes related facts appear to be widely separated, as, for example, the data of pH, and the observations on diastatic activity. That may be the consequence of a system of lecturing, however, since often the sequence of presentation in a series of lectures is not perfectly adapted to monographic presentation. Discussion of the amylases is rather brief, in view of the prominence of these enzymes in present milling and baking practices, and the student of the subject might appreciate more expansive treatment than is accorded them here.

Such a large scope of subject matter is difficult of condensation within the confines of a book of this type. Dr. Swanson has made an excellent choice of material and one suspects that his greatest problem as an author involved choosing what to omit. Some of us would have been glad had he made the volume twice as large.

In view of Dr. Swanson's interest in mechanical testing of dough, the last two chapters in this volume entitled: XXV. Some factors at the basis of the physical property of dough, and XXVI. Physical tests to measure quality, will be of particular interest to those who have followed his work in this field. The author's recording dough mixer is clearly depicted, and an analysis of curves recorded by this device is presented. Earlier in the book (p. 37) curves are presented resulting from tests of a few characteristic varieties or classes of American wheats.

The time was ripe for a new book in this field written in the English language. Dr. Swanson has supplied certain needs admirably and his contribution will be welcomed.

C. H. Bailey